US008230583B2

(12) United States Patent
Lille

(10) **Patent No.: US 8,230,583 B2**
(45) **Date of Patent: Jul. 31, 2012**

(54) **METHOD FOR MANUFACTURING A MAGNETIC WRITE HEAD**

(75) Inventor: **Jeffrey S. Lille**, Sunnyvale, CA (US)

(73) Assignee: **Hitachi Global Storage Technologies Netherlands B.V.**, Amsterdam (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

(21) Appl. No.: **12/646,884**

(22) Filed: **Dec. 23, 2009**

(65) **Prior Publication Data**

US 2010/0126001 A1 May 27, 2010

Related U.S. Application Data

(62) Division of application No. 11/683,972, filed on Mar. 8, 2007.

(51) **Int. Cl.**
G11B 5/127 (2006.01)
H04R 31/00 (2006.01)

(52) **U.S. Cl.** **29/603.16**; 29/603.11; 29/603.13; 29/603.14; 29/603.15; 29/603.18; 216/22; 216/39; 216/41; 216/48; 216/65; 360/125.02; 360/125.03; 360/125.13; 360/125.3; 360/125.33; 451/5; 451/41

(58) **Field of Classification Search** 29/603.11, 29/603.13–603.16, 603.18; 216/22, 39, 41, 216/48, 65; 360/125.02, 125.03, 125.13, 360/125.3, 125.33, 121, 122, 317; 451/5, 451/41

See application file for complete search history.

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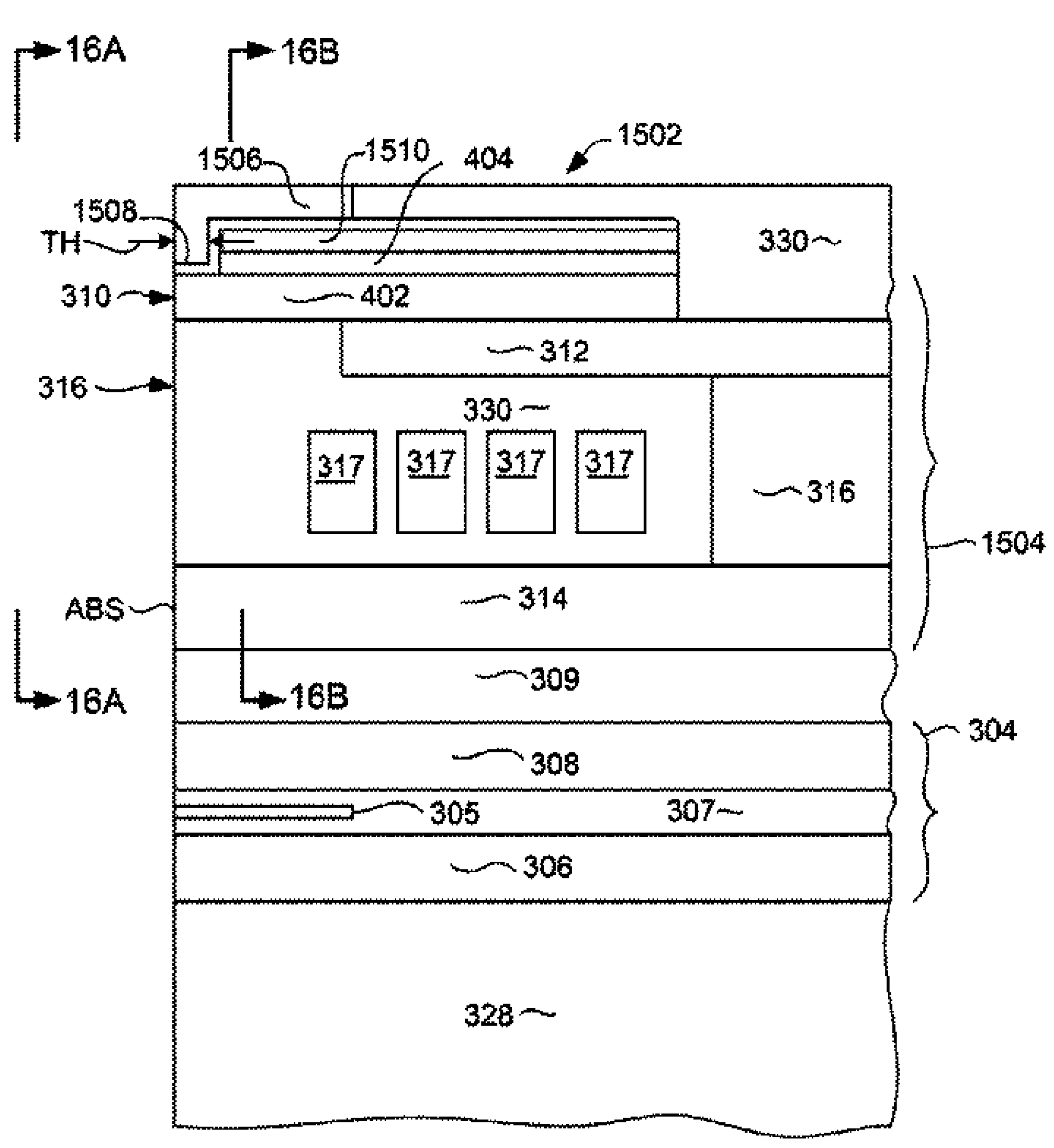
Primary Examiner — Paul D Kim
(74) *Attorney, Agent, or Firm* — Zilka-Kotab, PC

(57) **ABSTRACT**

A method for self aligning a lapping guide with a structure of a write pole. A write pole is formed over a substrate and an electrically conductive material lapping guide material is deposited in a location that is removed from the write pole. A mask is then formed over a portion of the write pole and a portion of the electrically conductive material. A material removal process such as reactive ion etching can then be performed to remove a portion of the magnetic material that is not protected by the mask structure. An magnetic material is then electroplated over the write pole with the write pole, with the mask still in place. In this way, the electroplated material has an edge that is self aligned with an edge of the electrically conductive lapping guide material, both being defined by the same mask structure.

10 Claims, 57 Drawing Sheets



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Non-Final Office Action Summary from U.S. Appl. No. 12/646,858 dated May 31, 2012.

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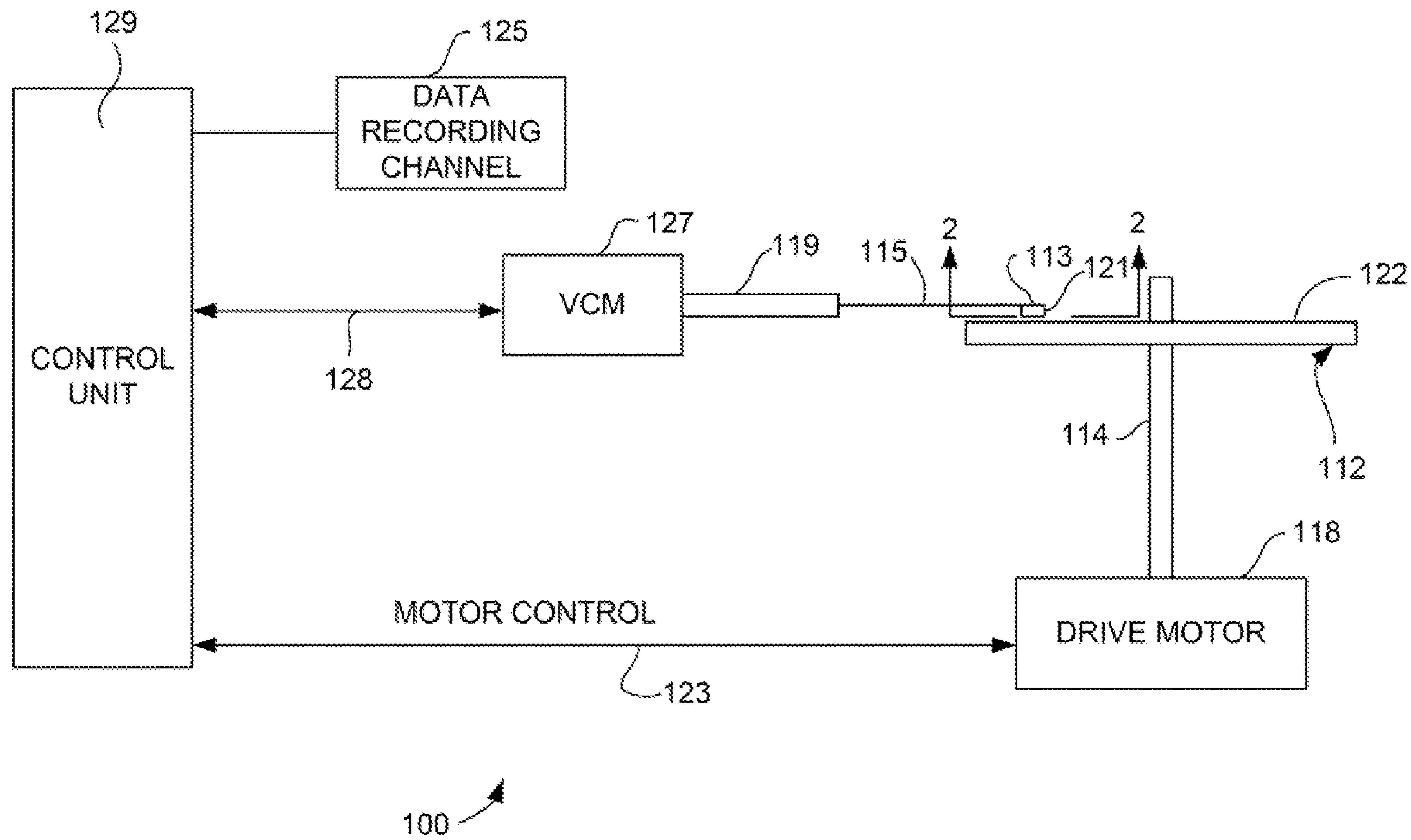
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MOTOR CONTROL
DRIVE MOTOR
123
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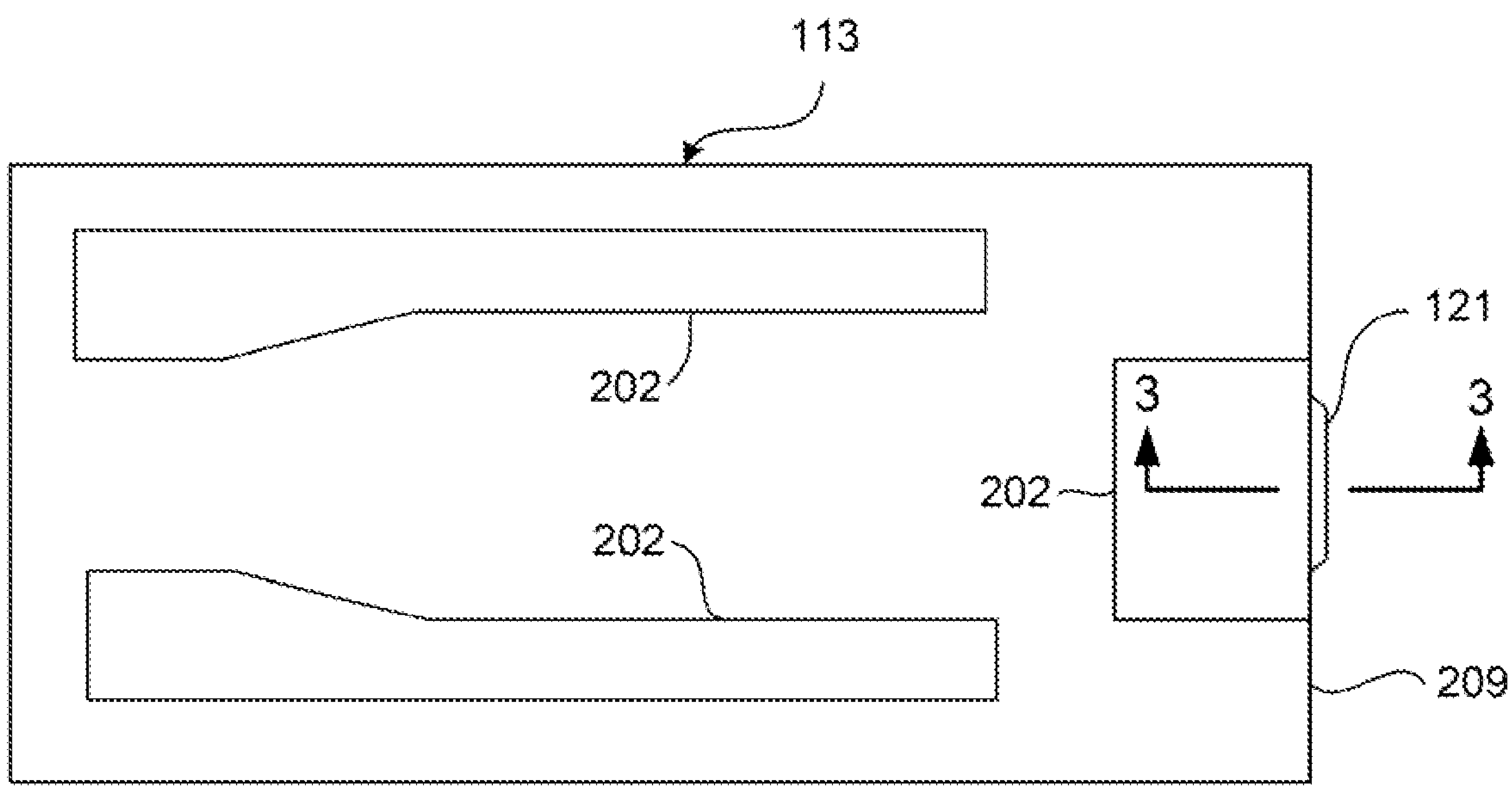
FIG. 1



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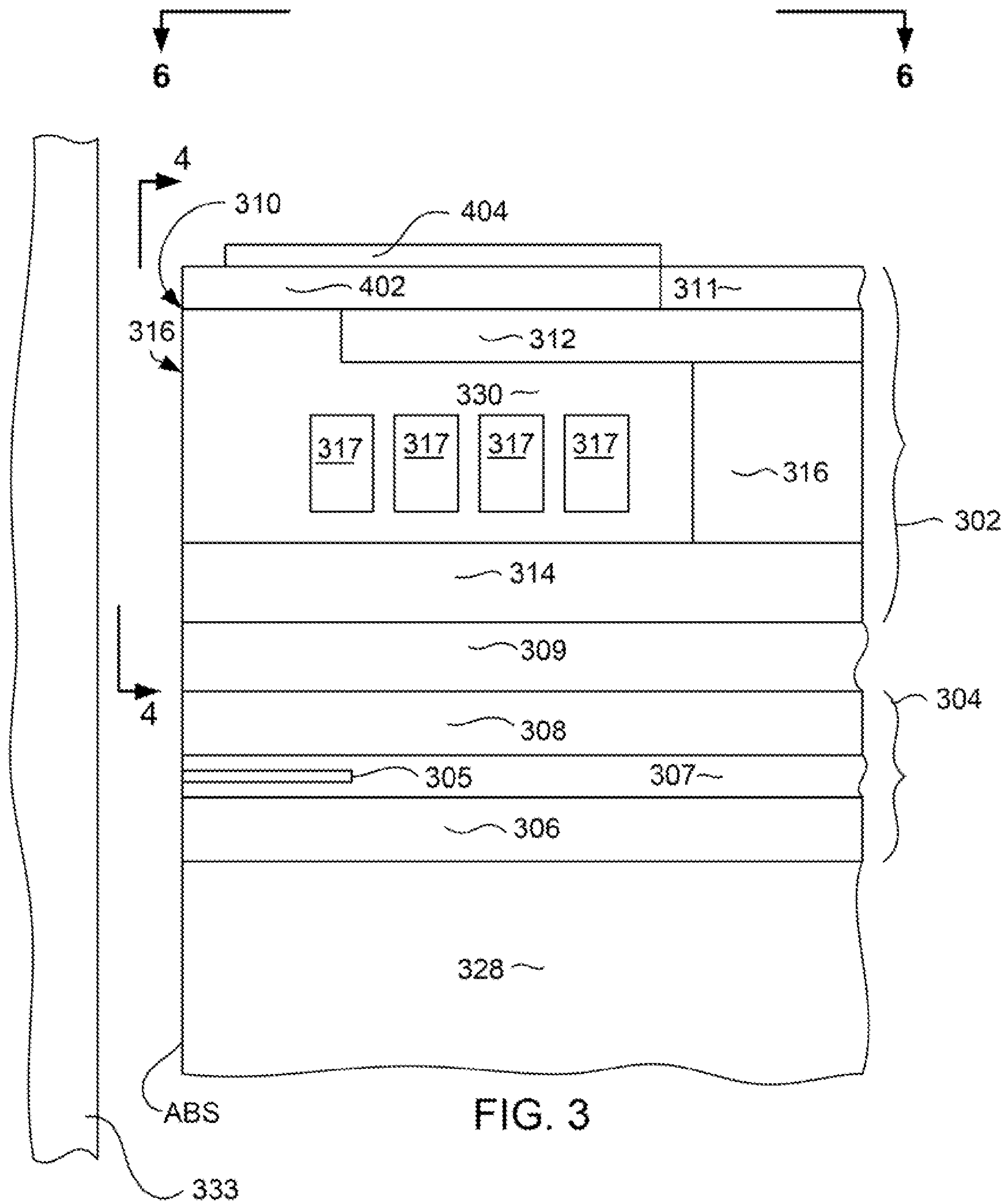
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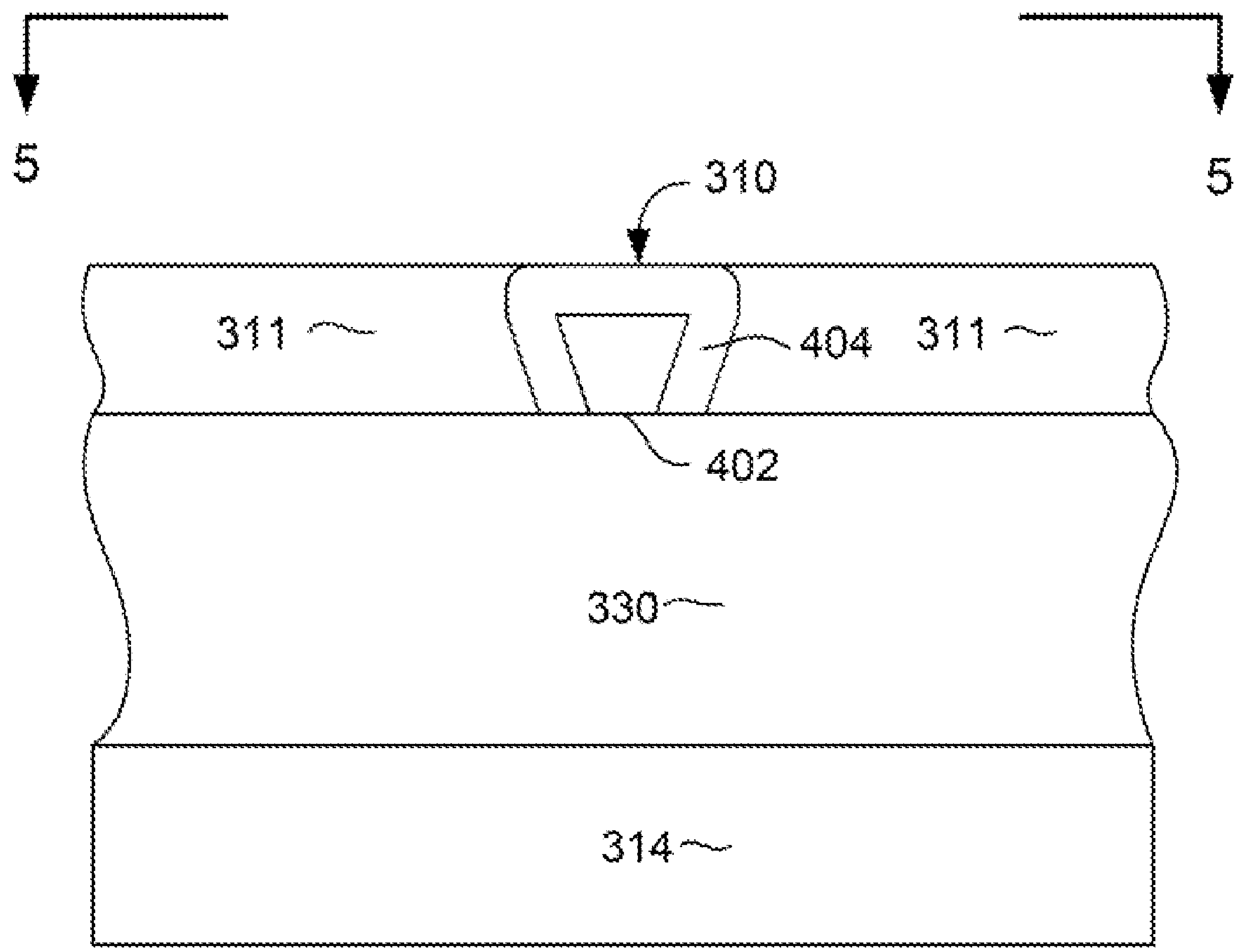
FIG. 3



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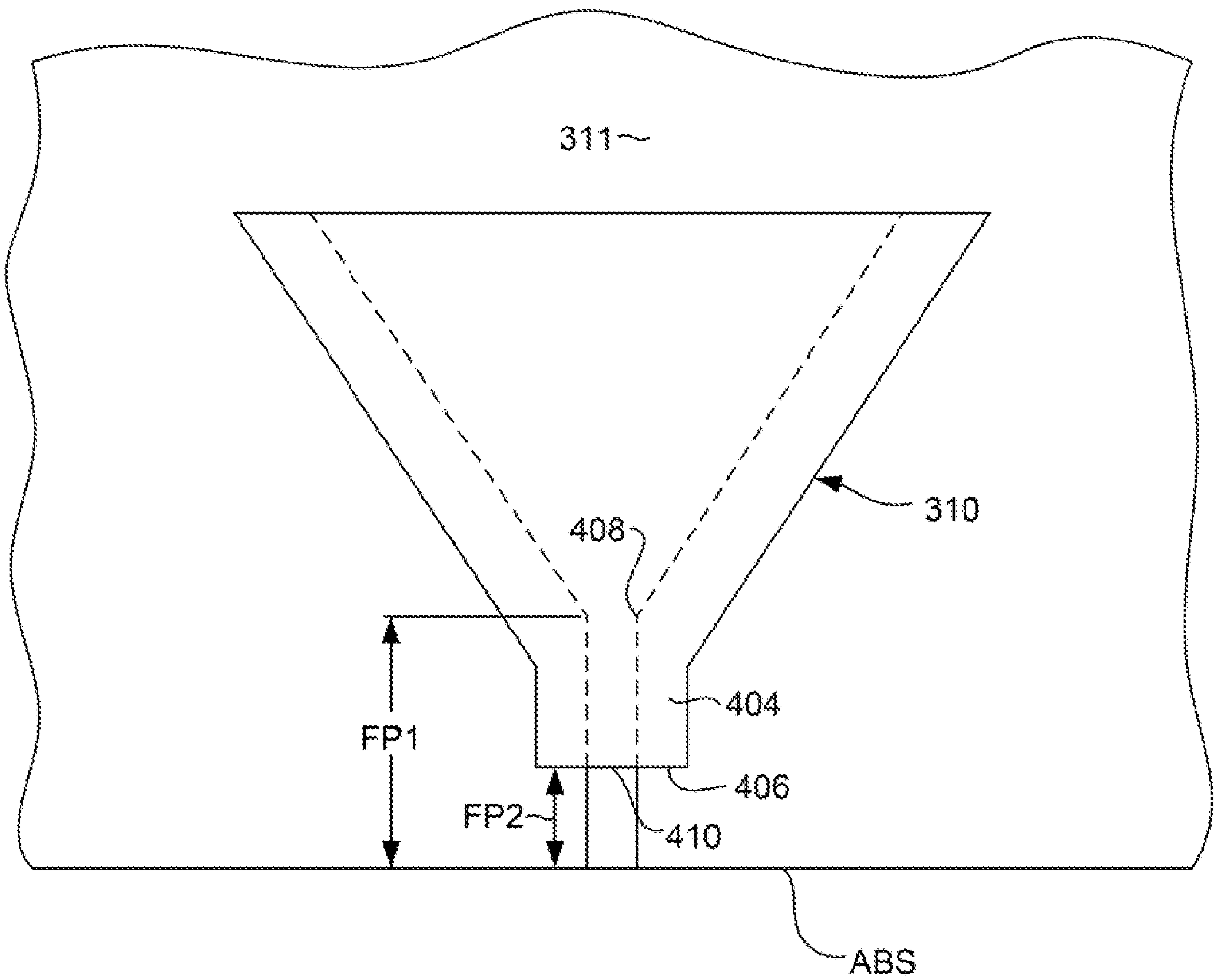

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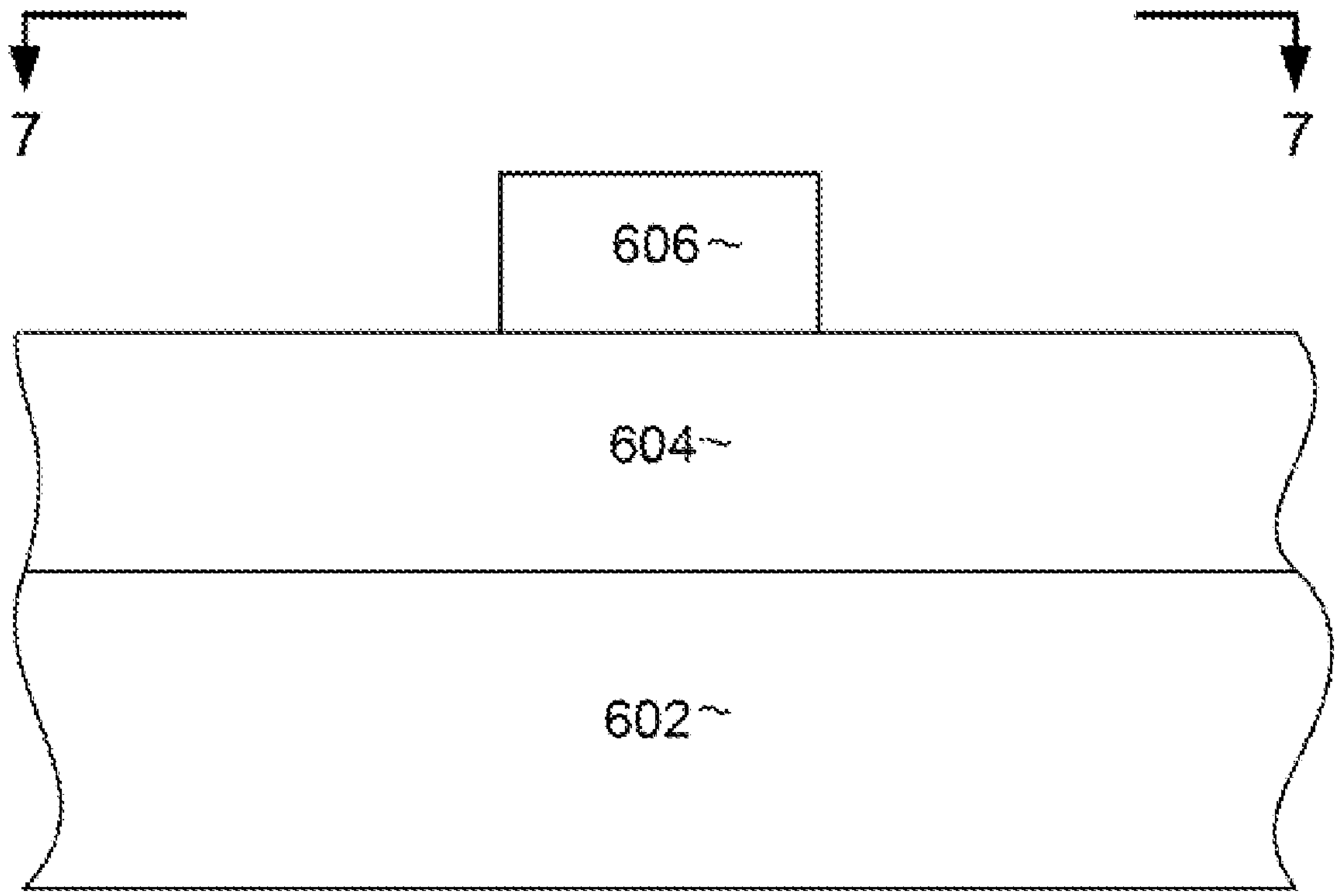

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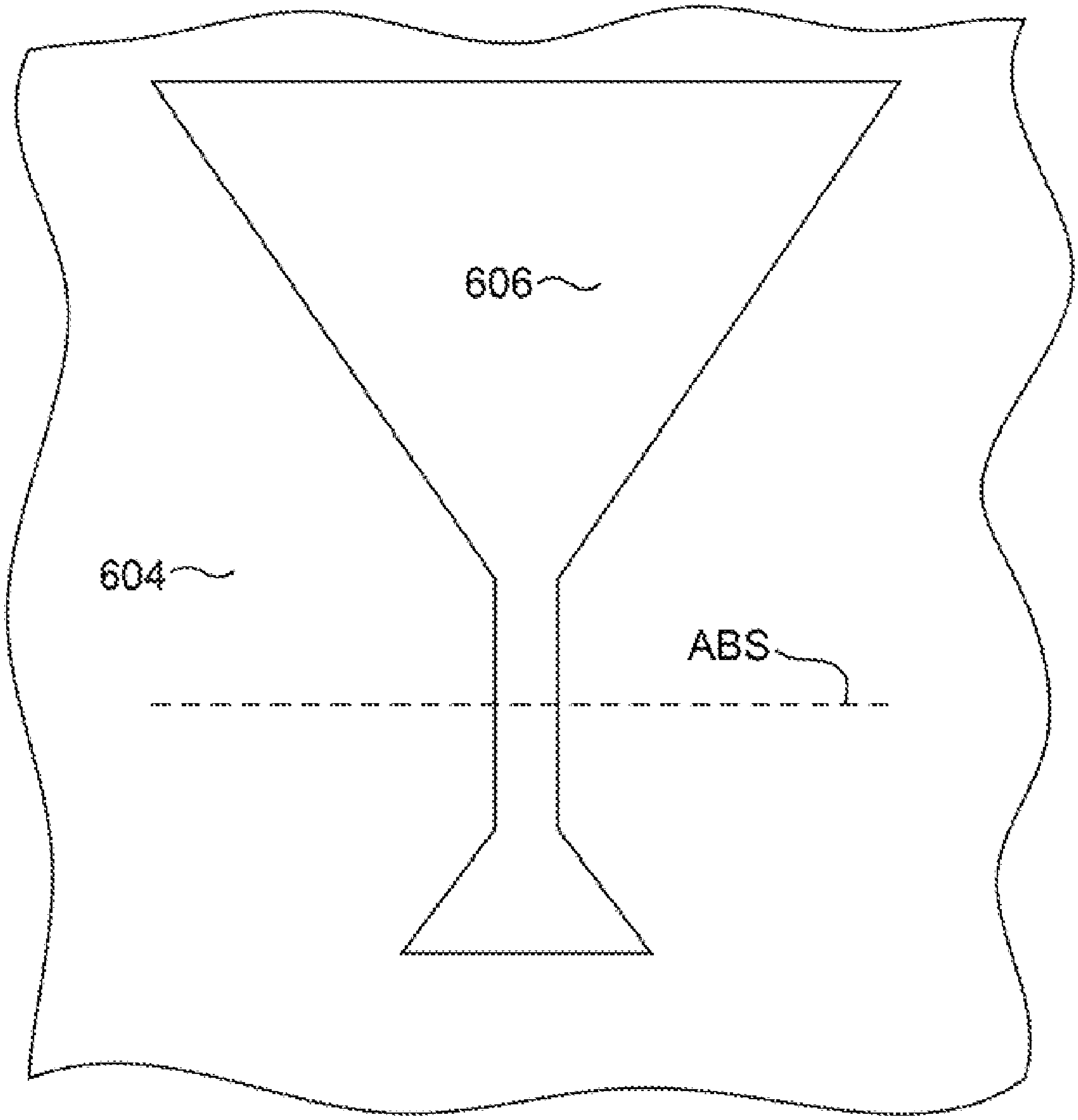

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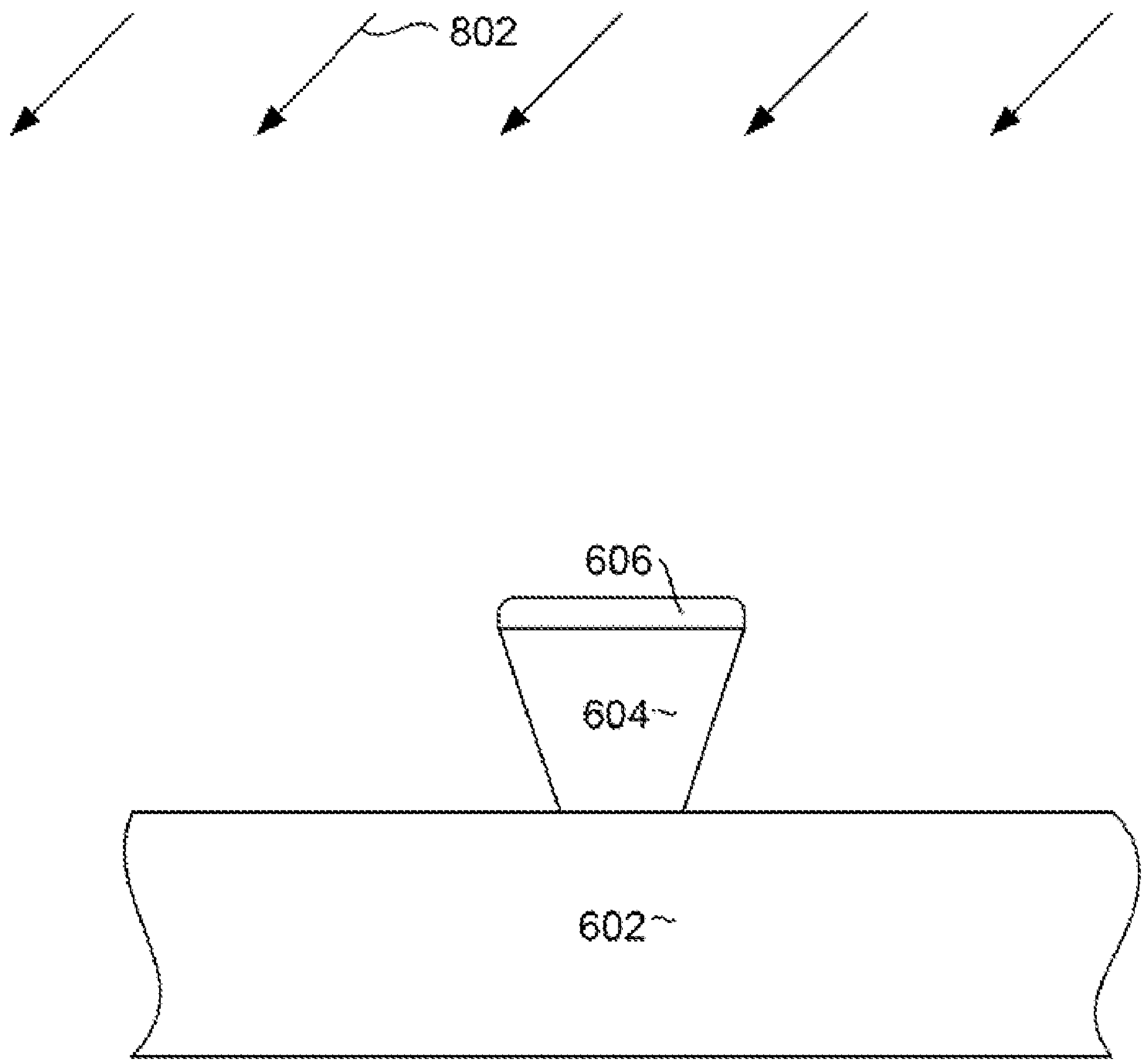

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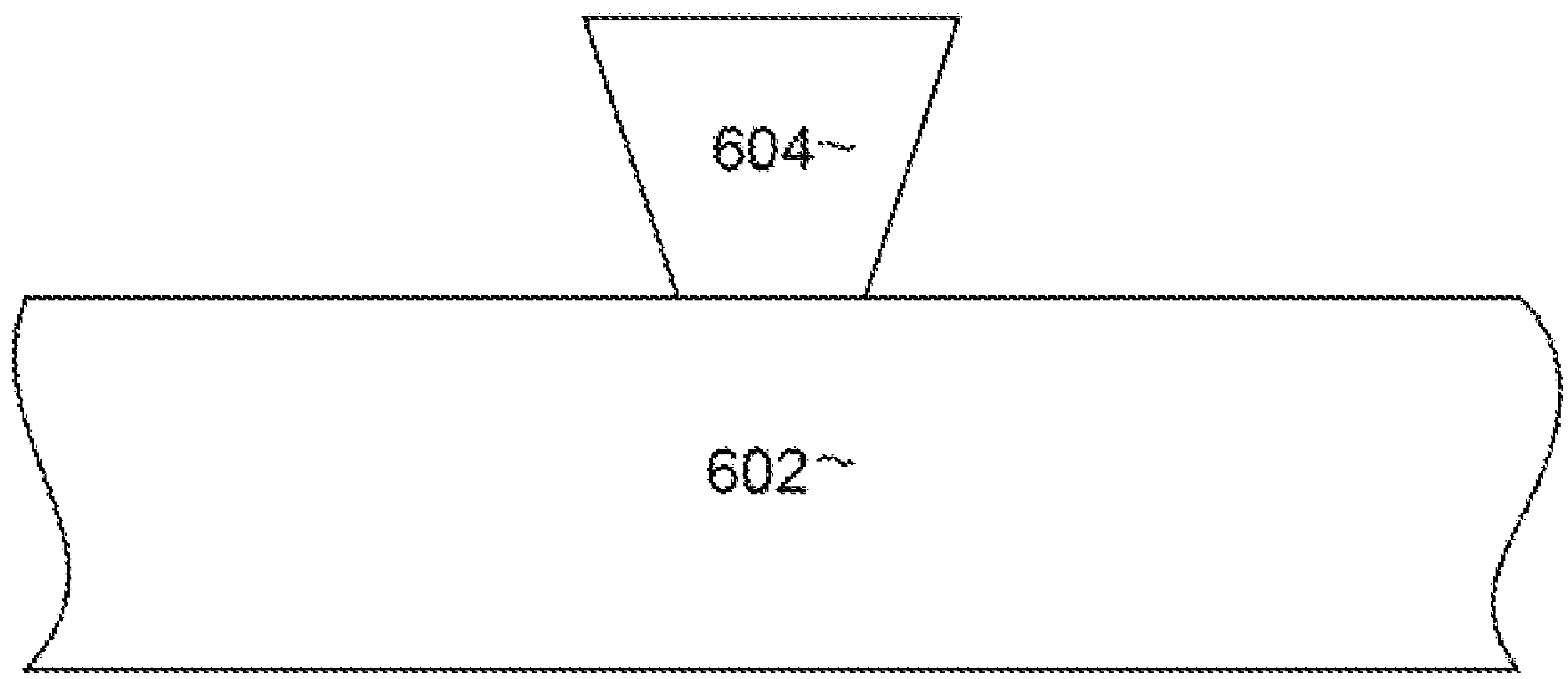

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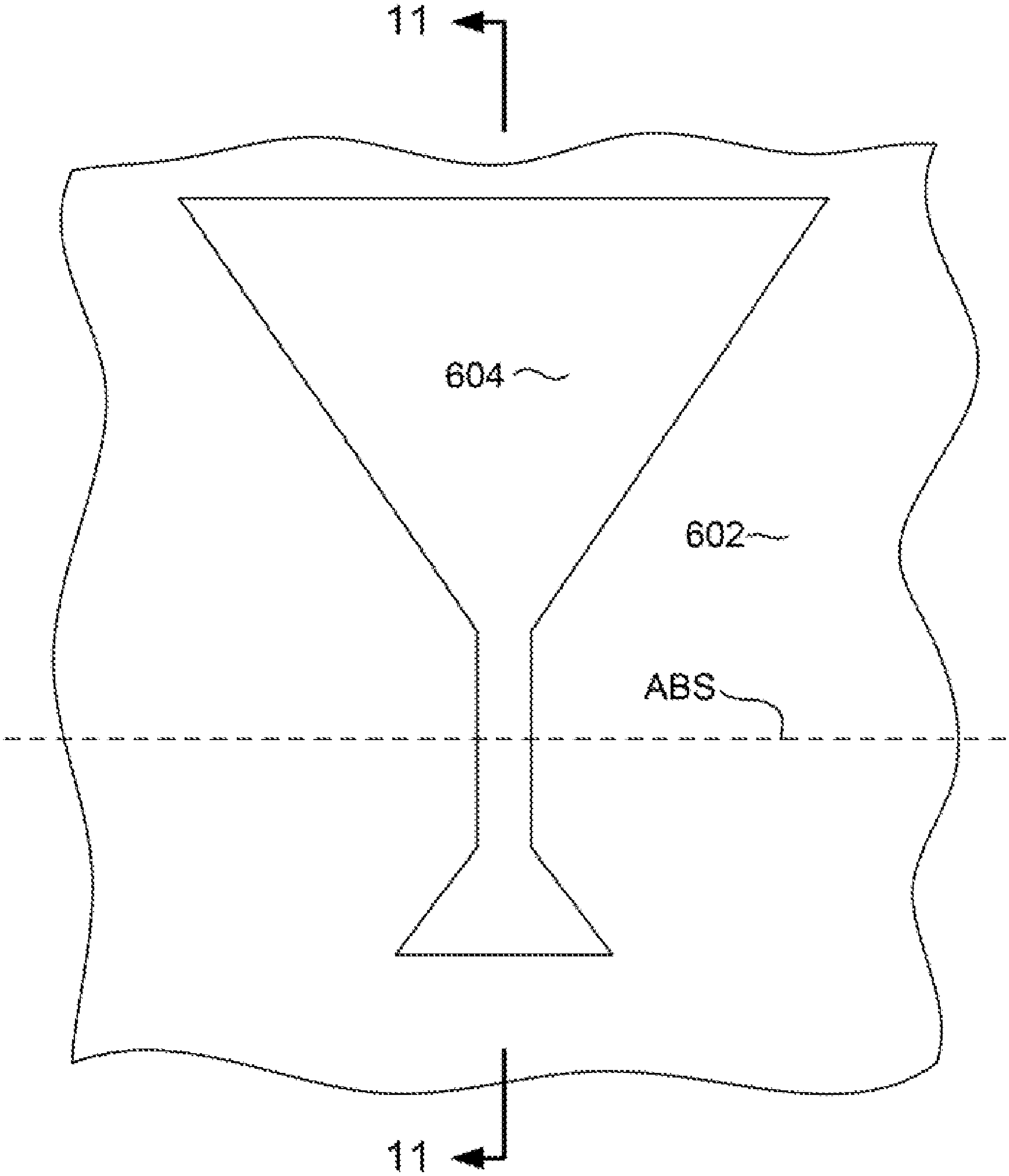

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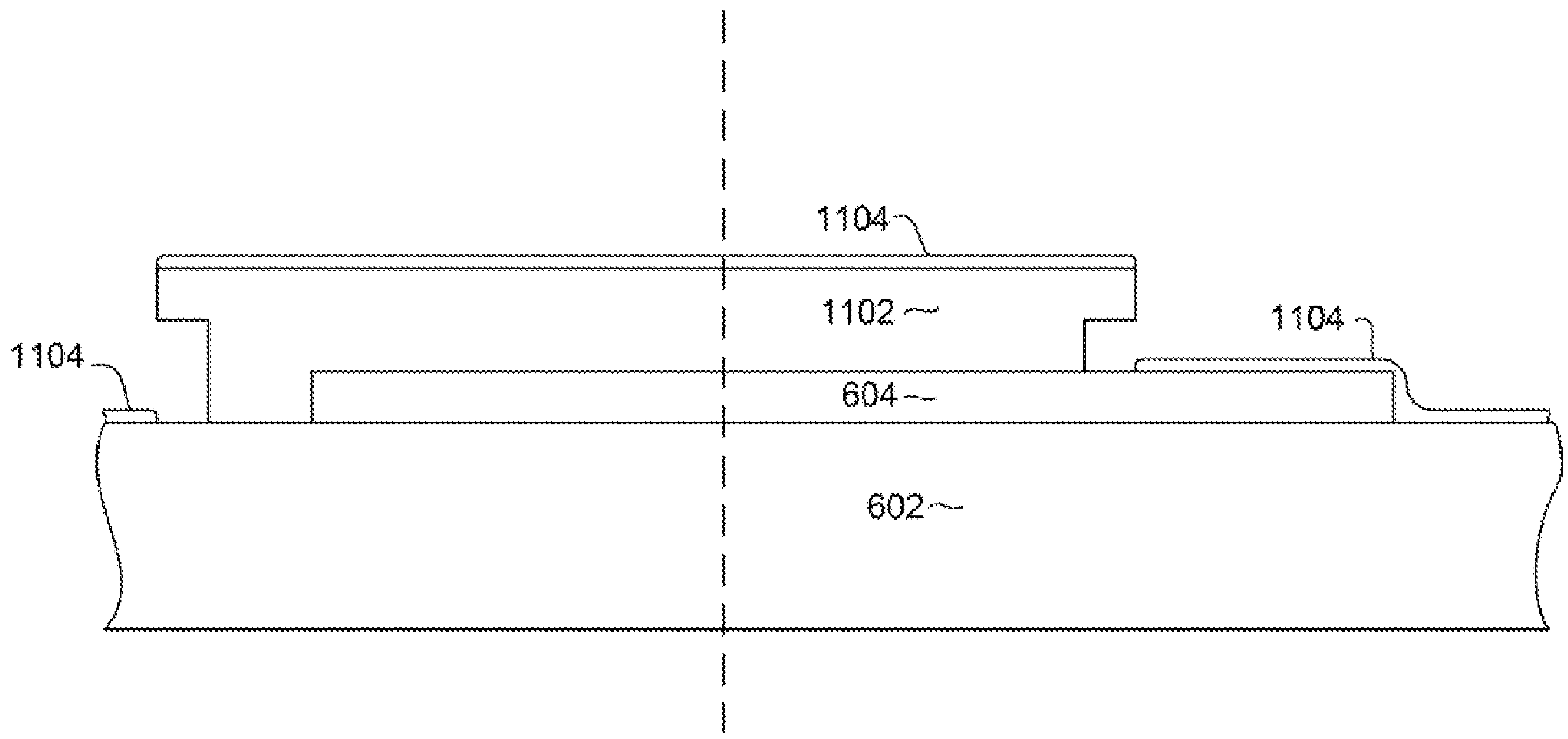
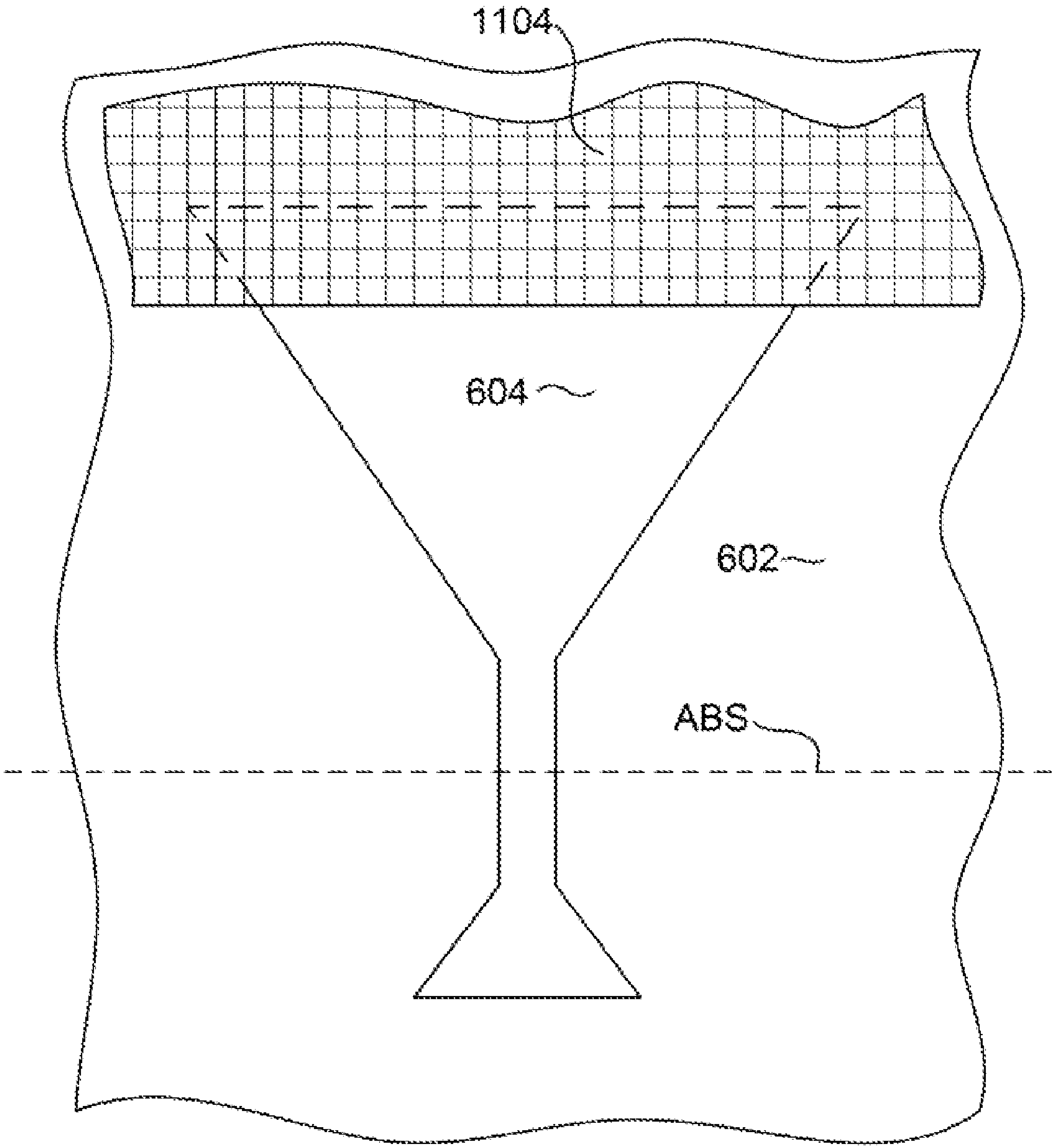


FIG. 11



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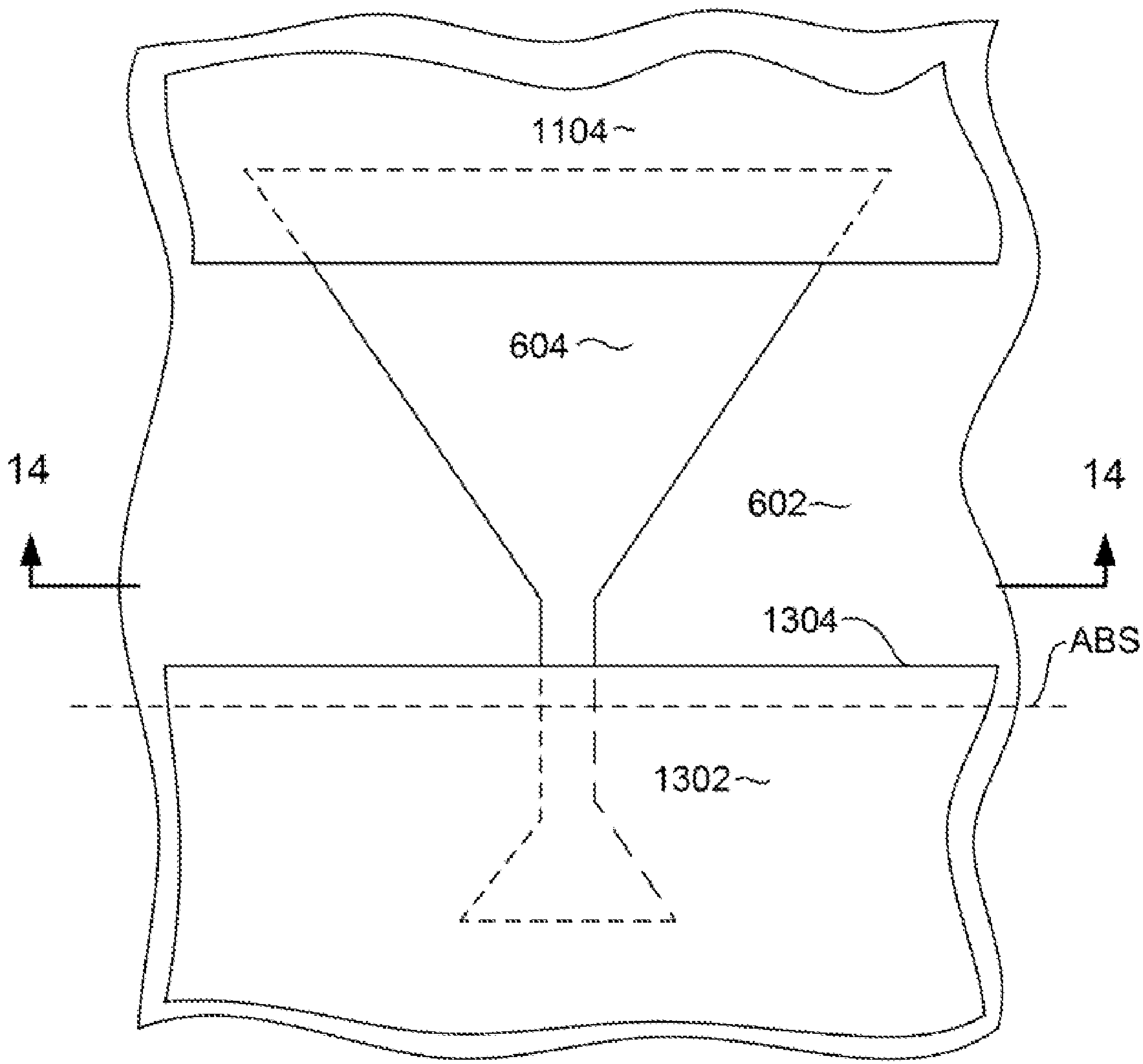

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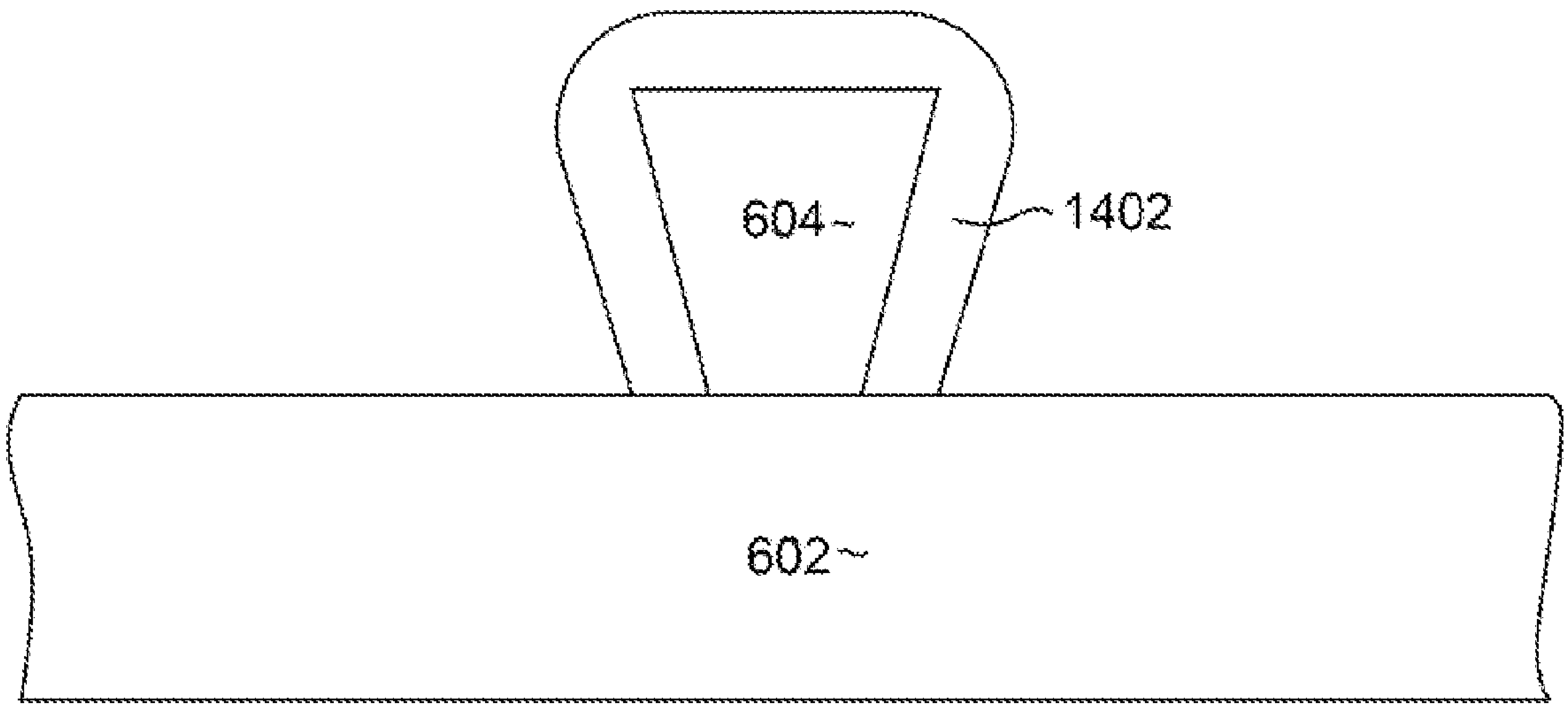

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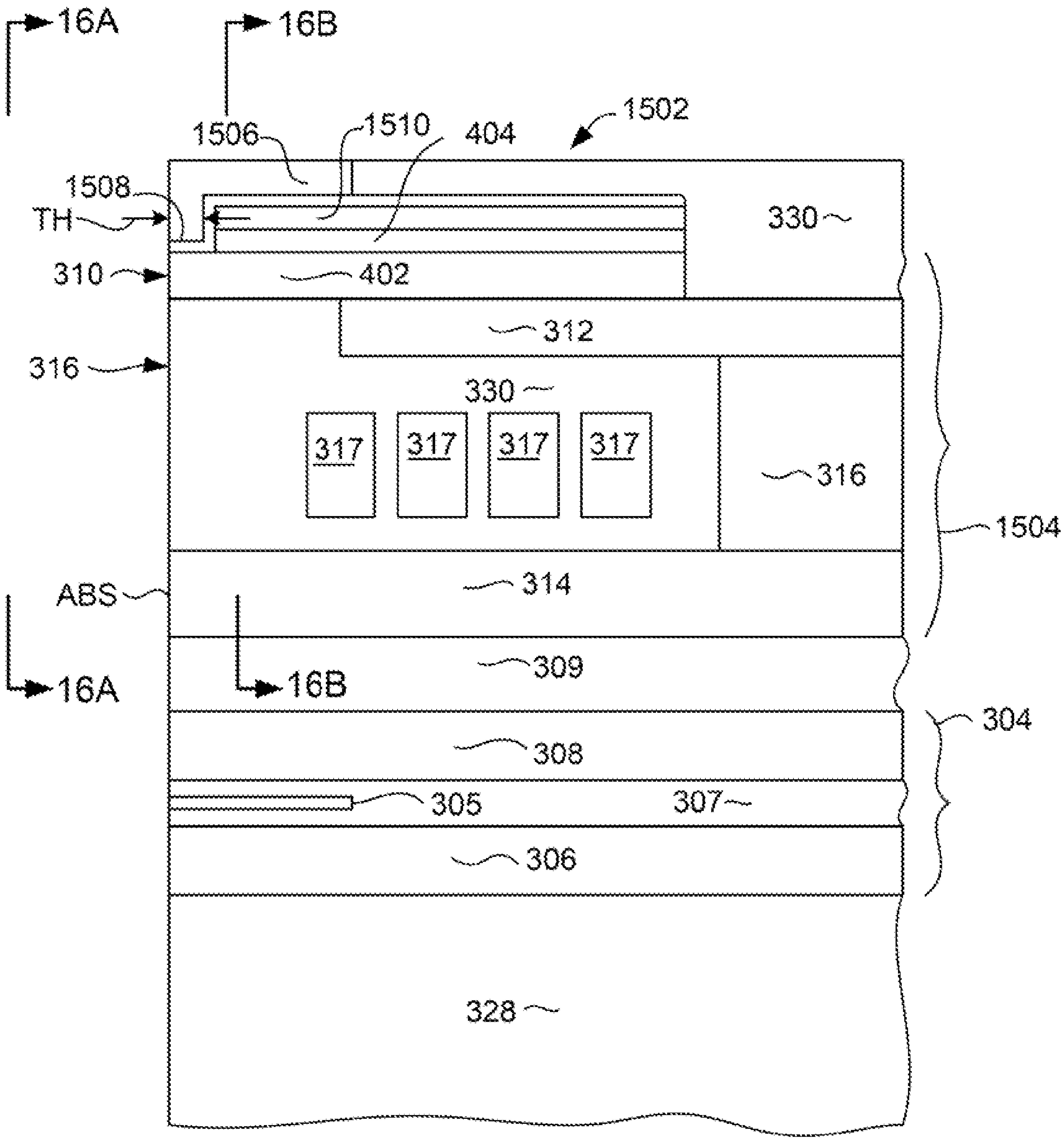
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FIG. 15

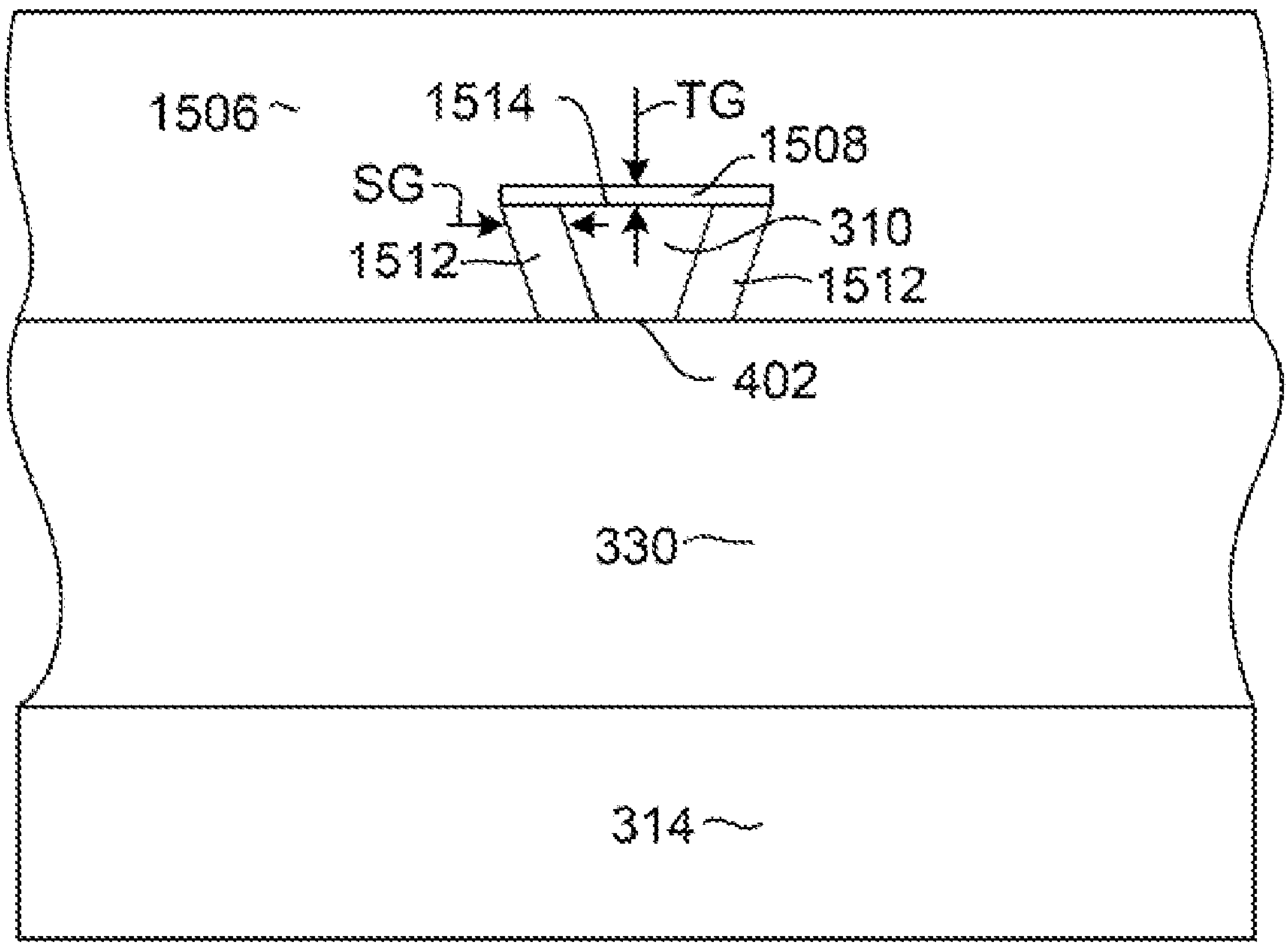
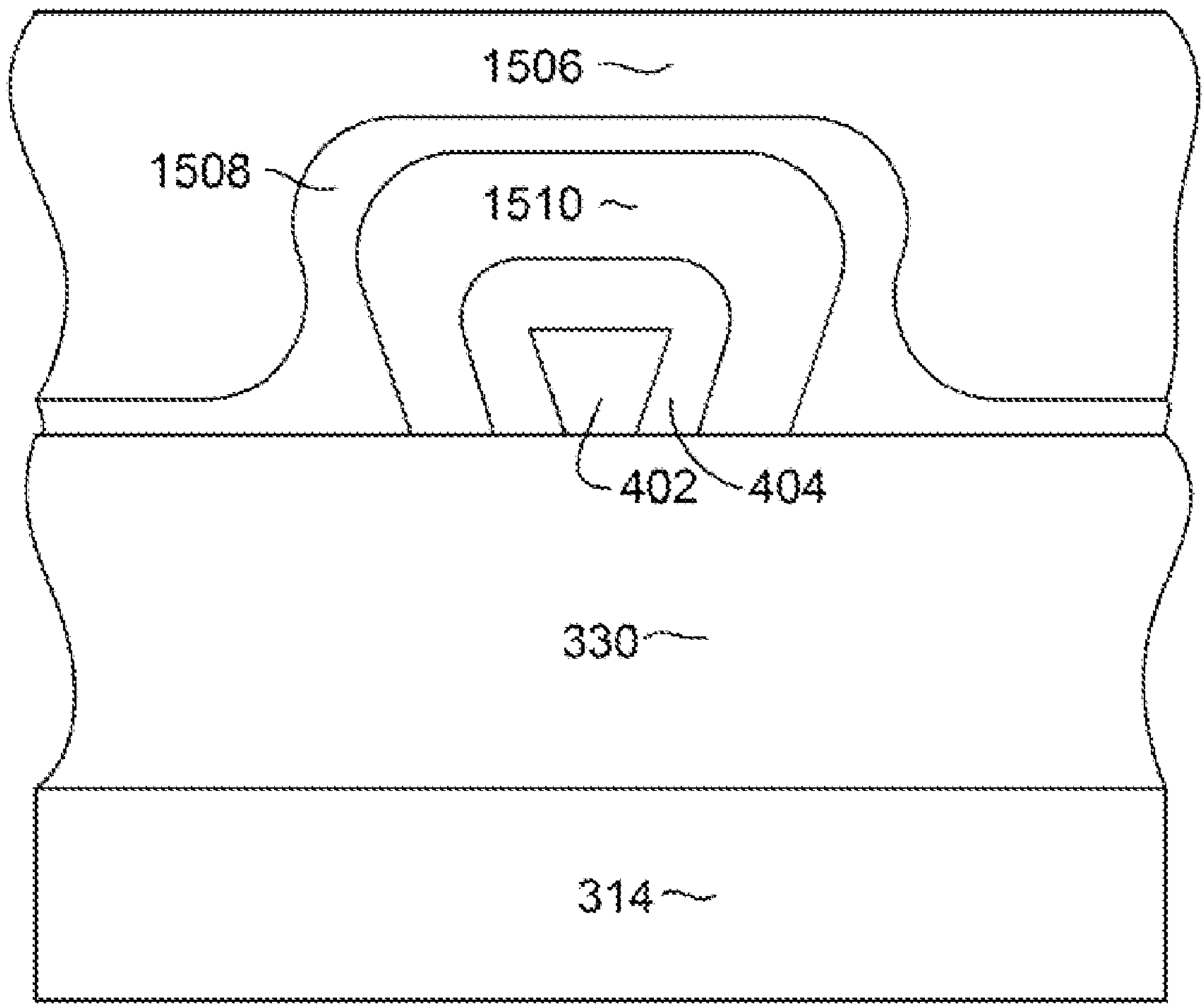


FIG. 16A



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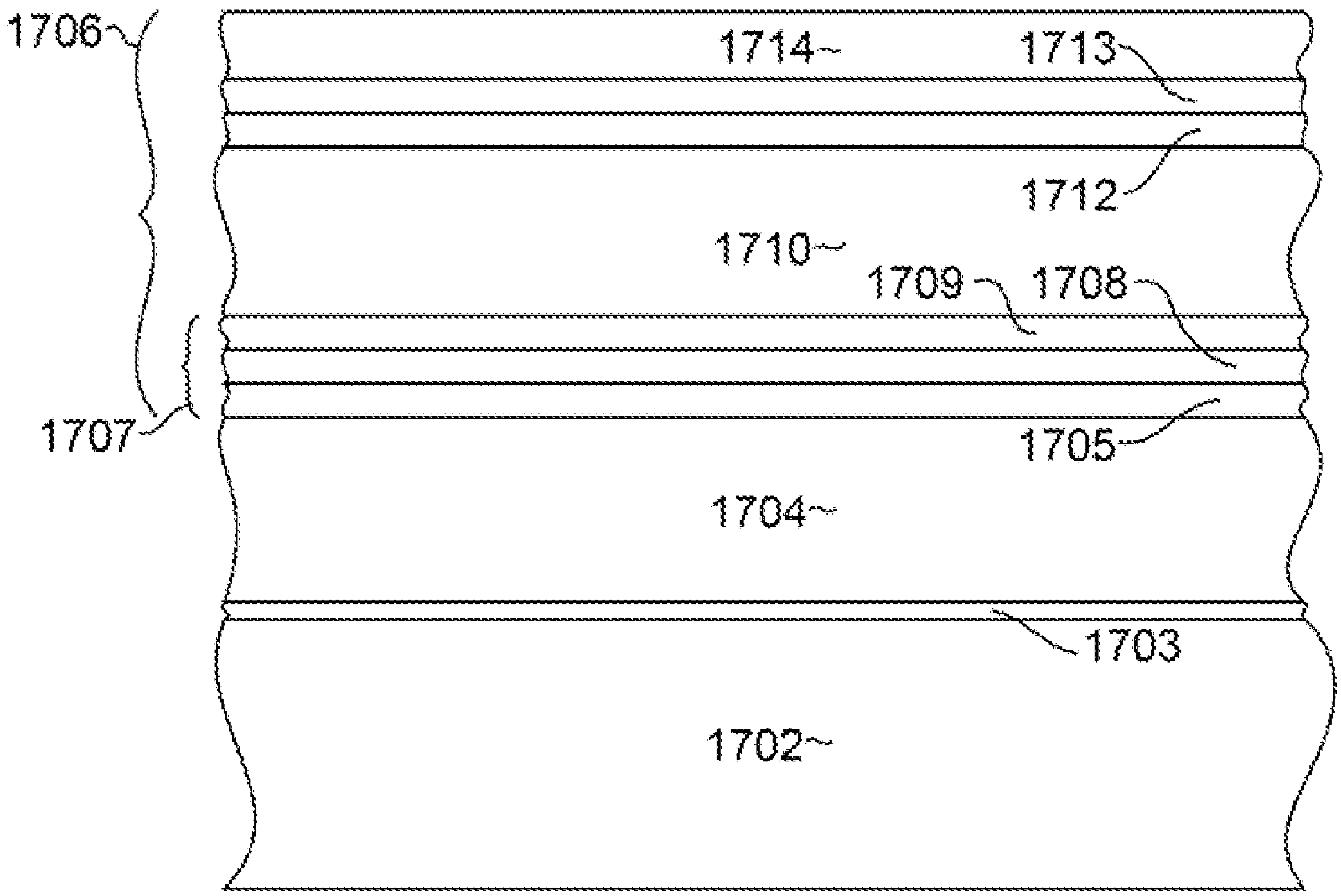

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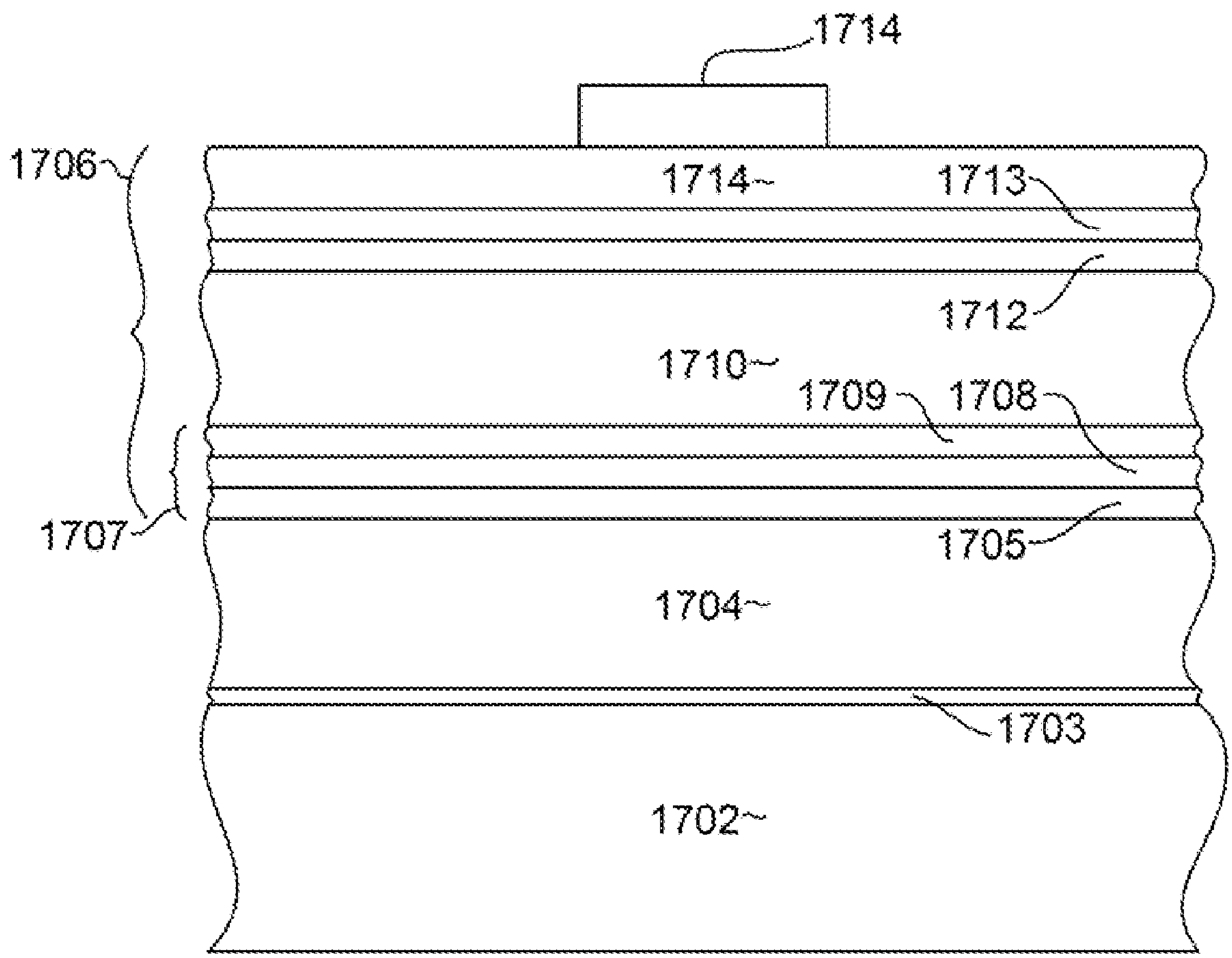
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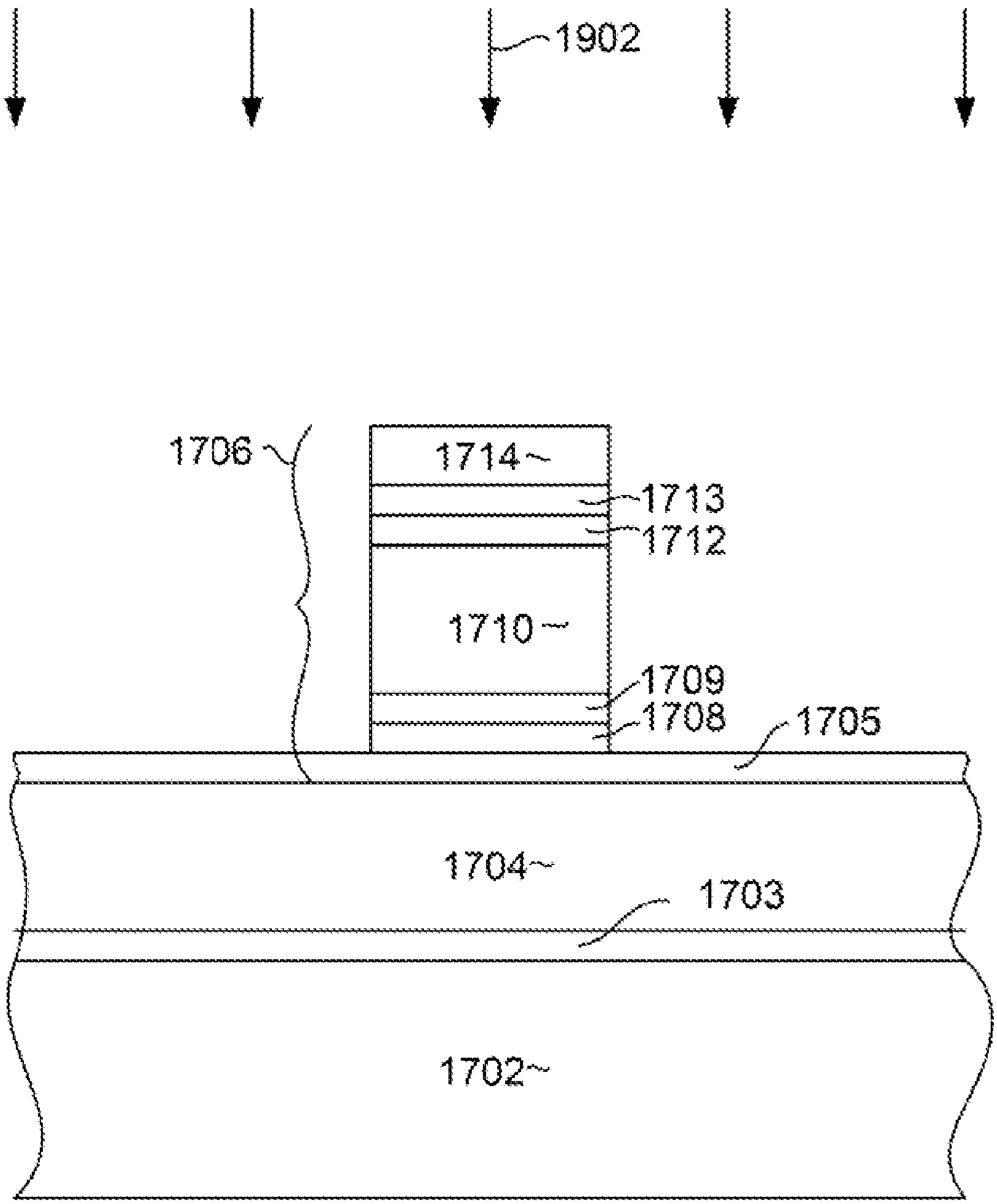
FIG. 18



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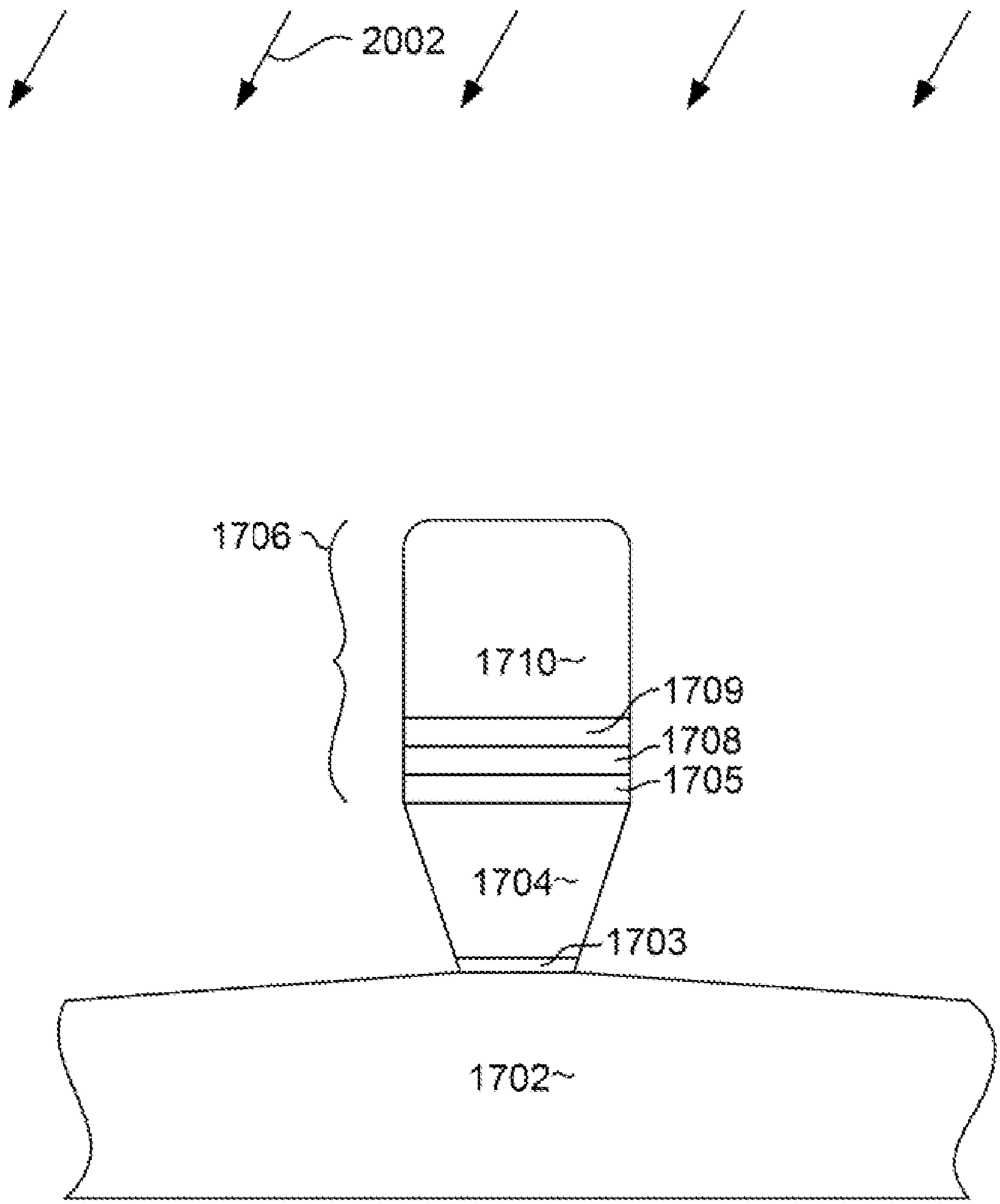


FIG. 20

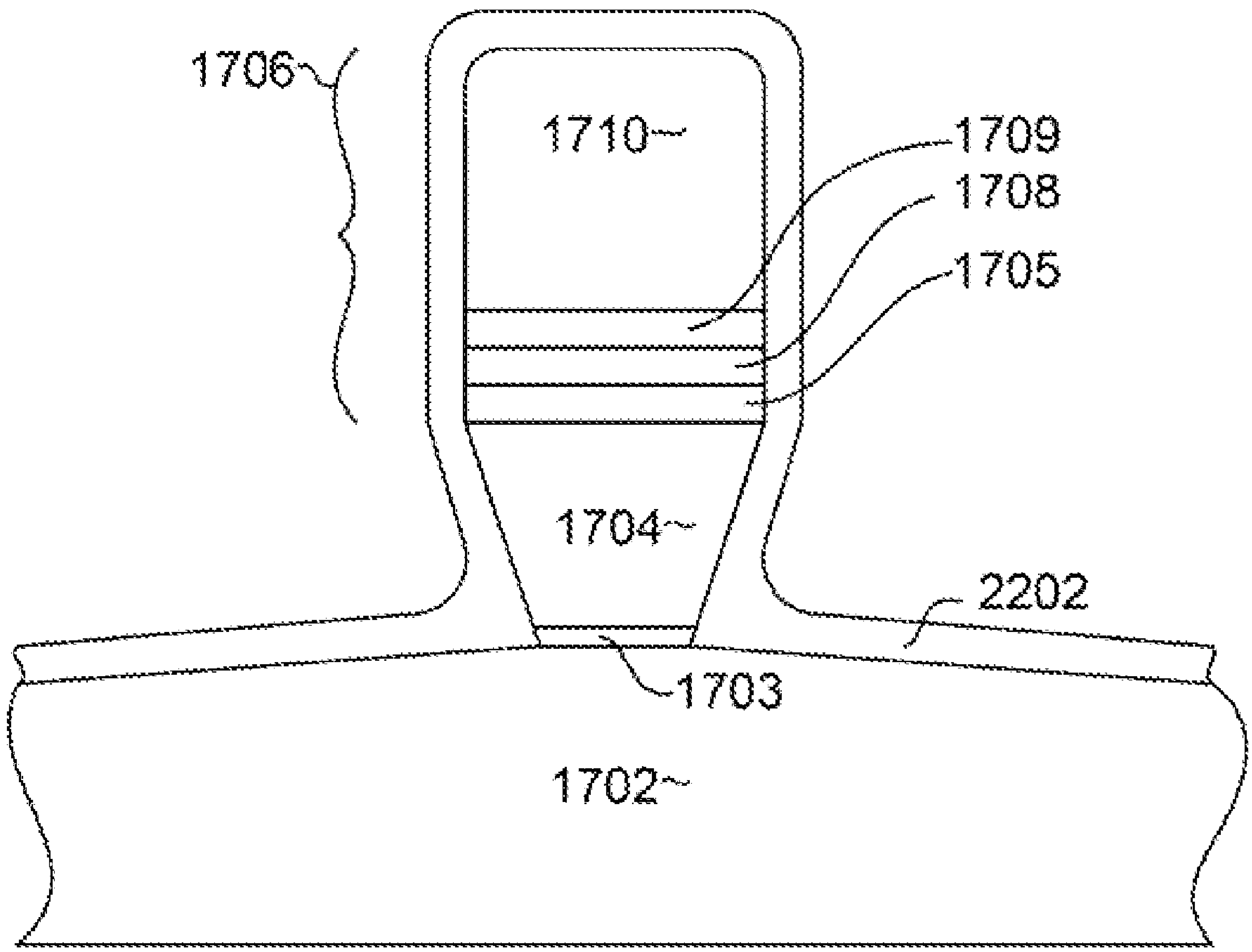


FIG. 21

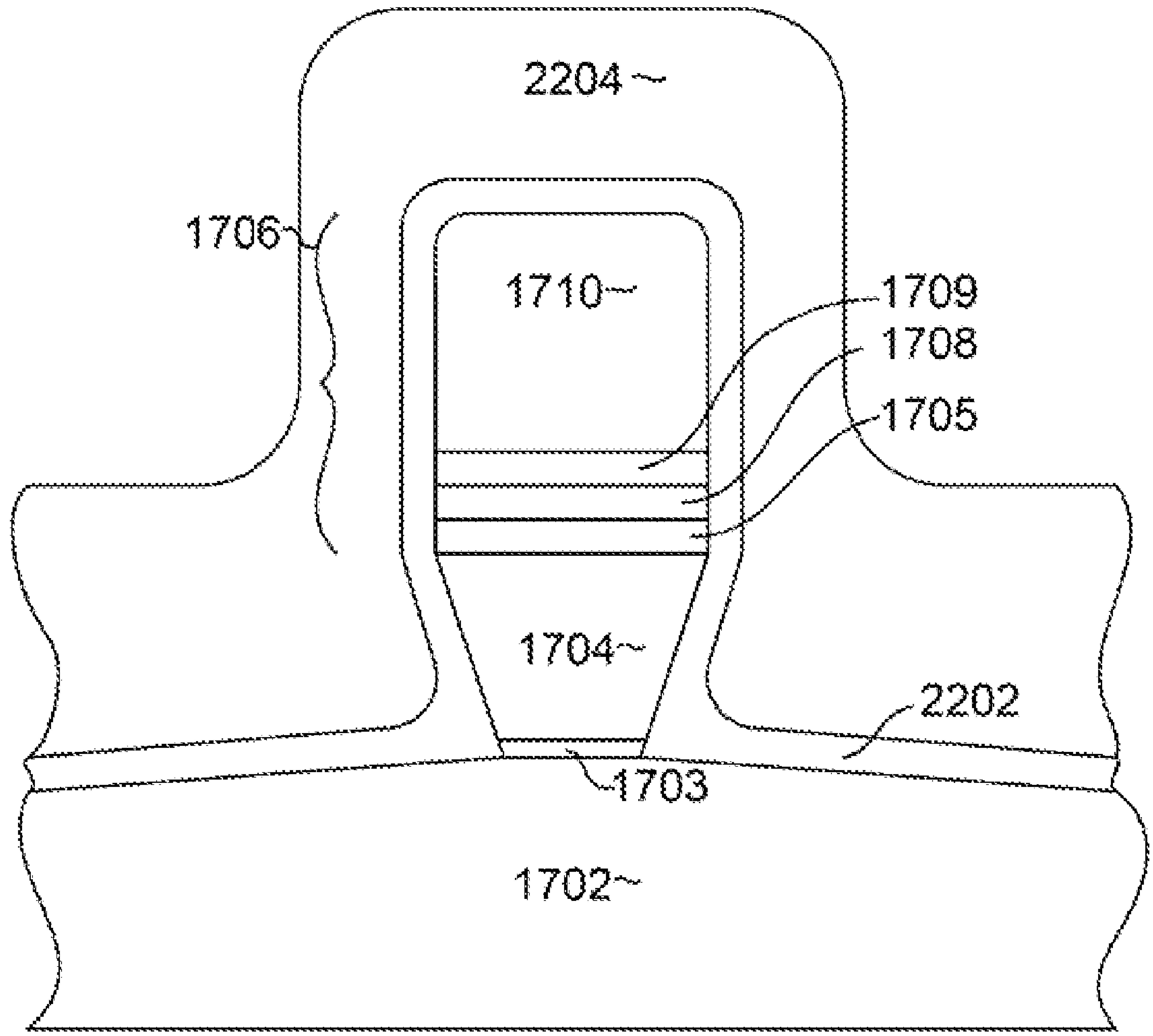


FIG. 22

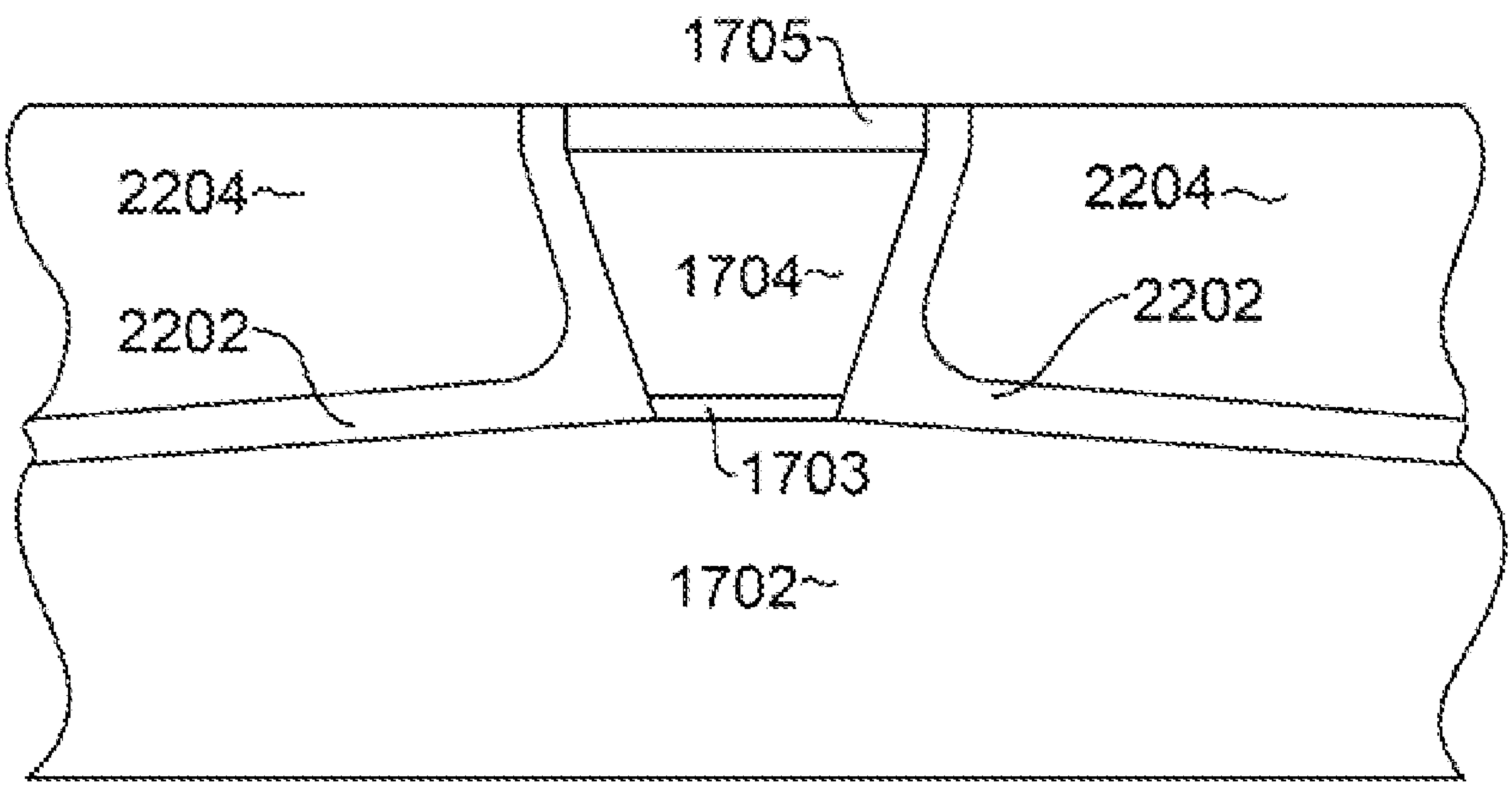


FIG. 23

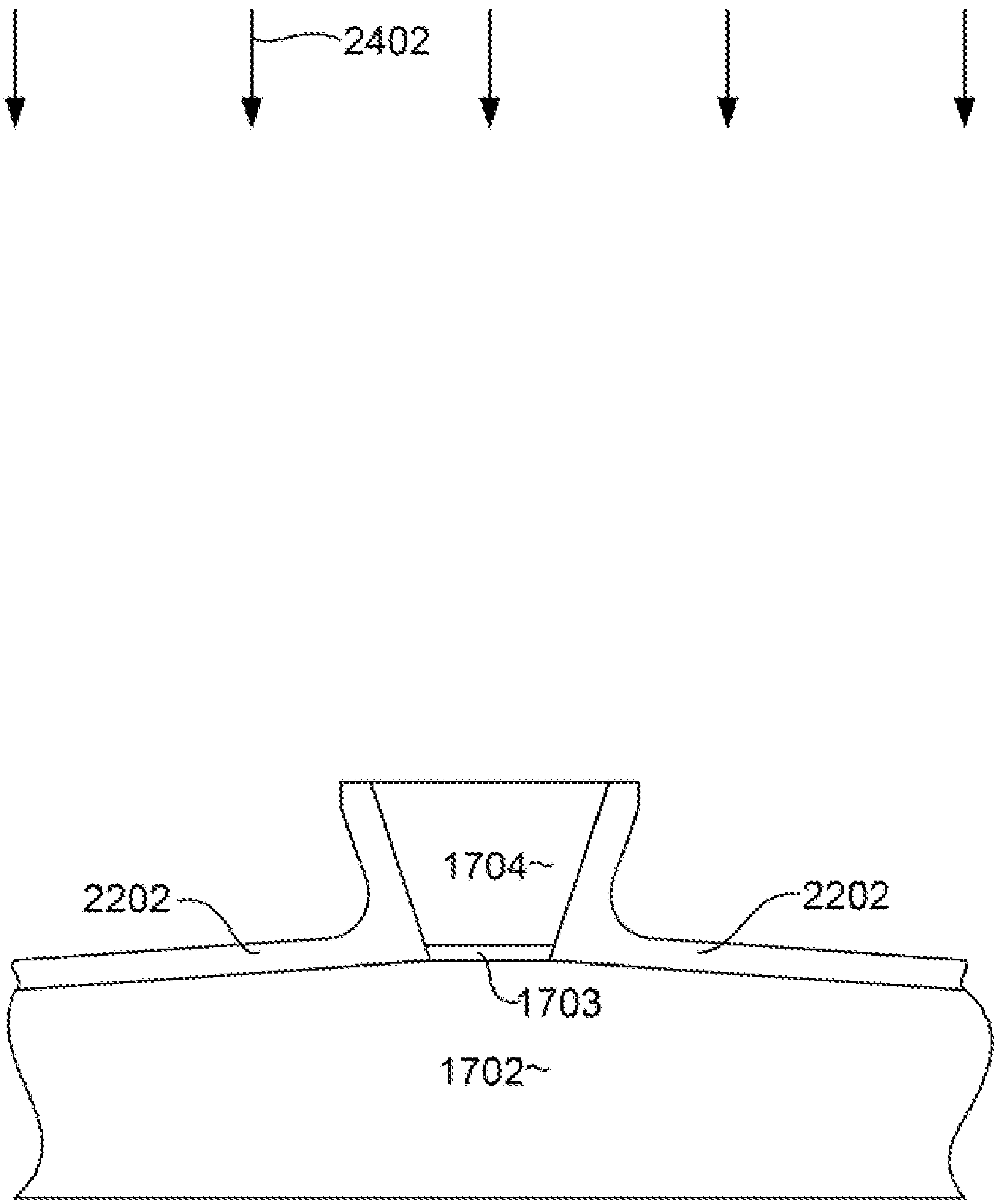


FIG. 24

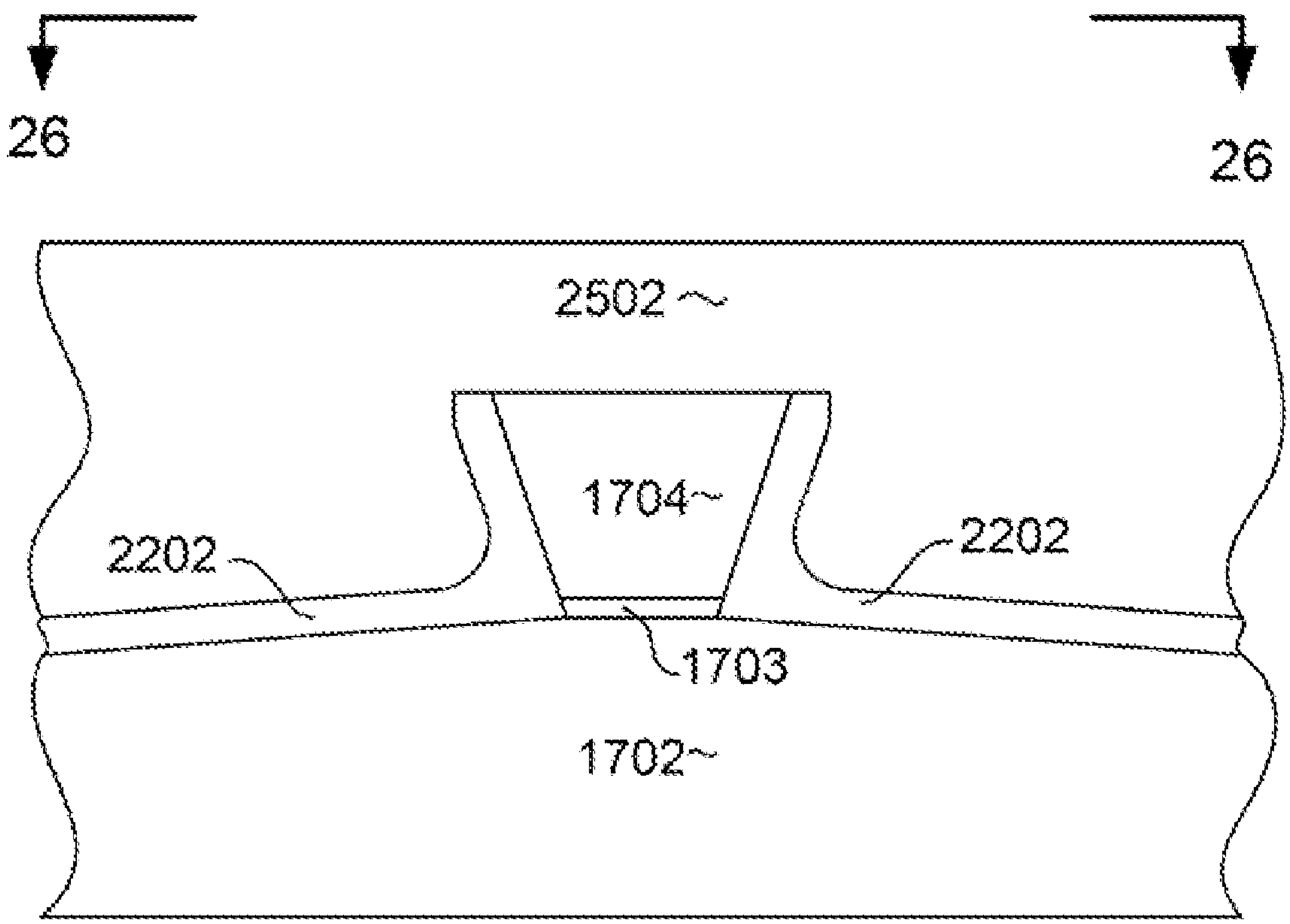


FIG. 25

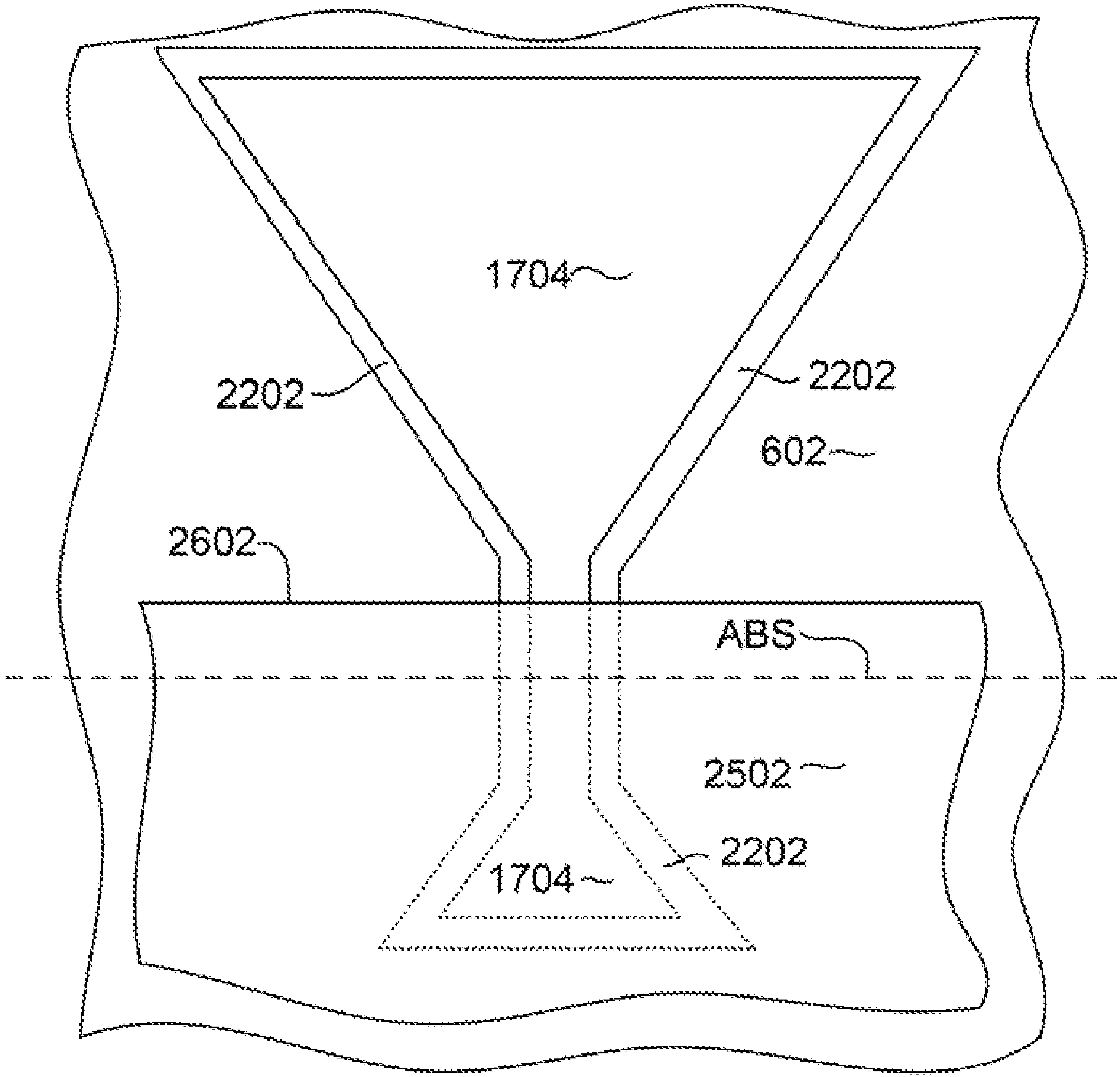


FIG. 26

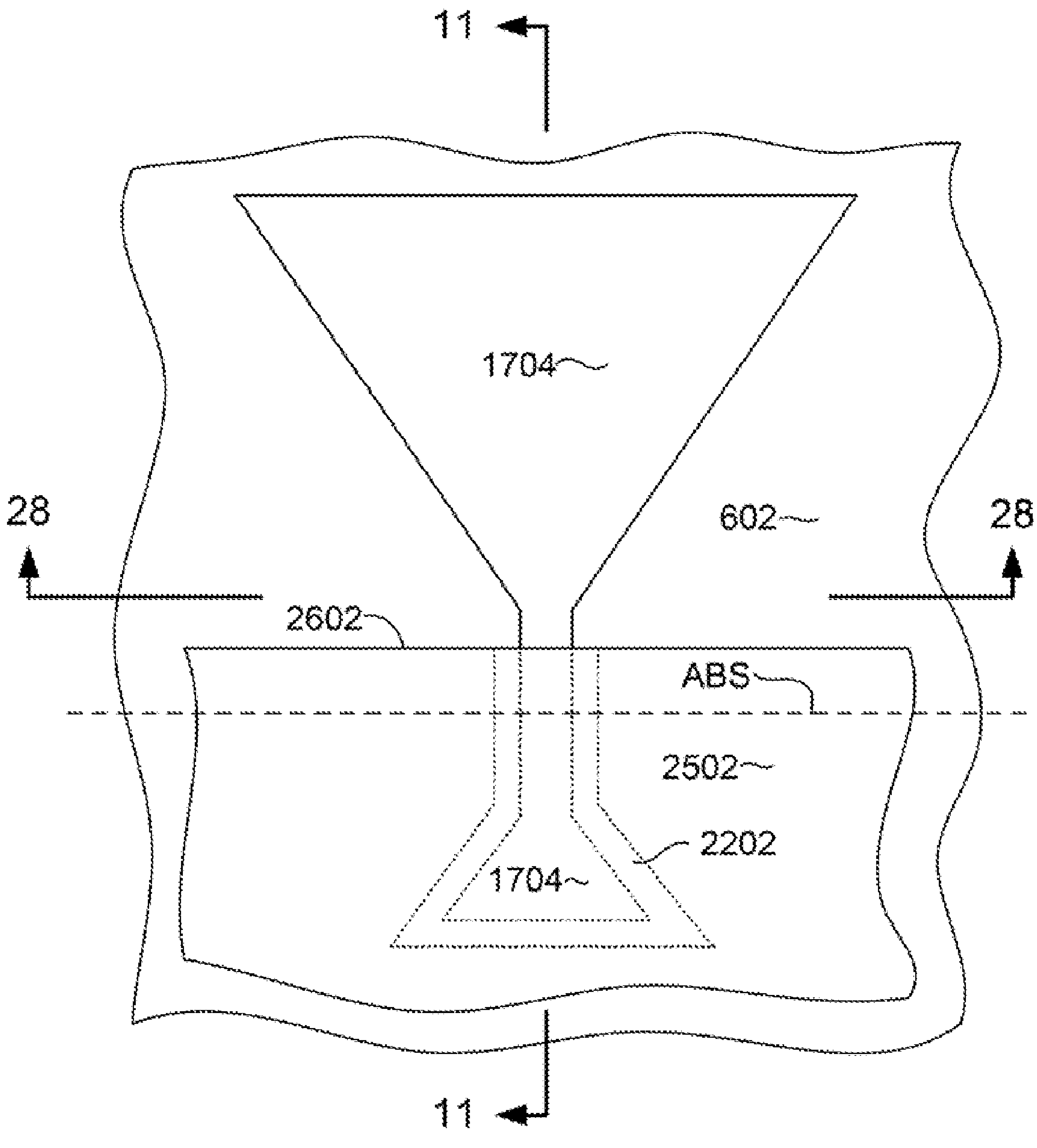


FIG. 27

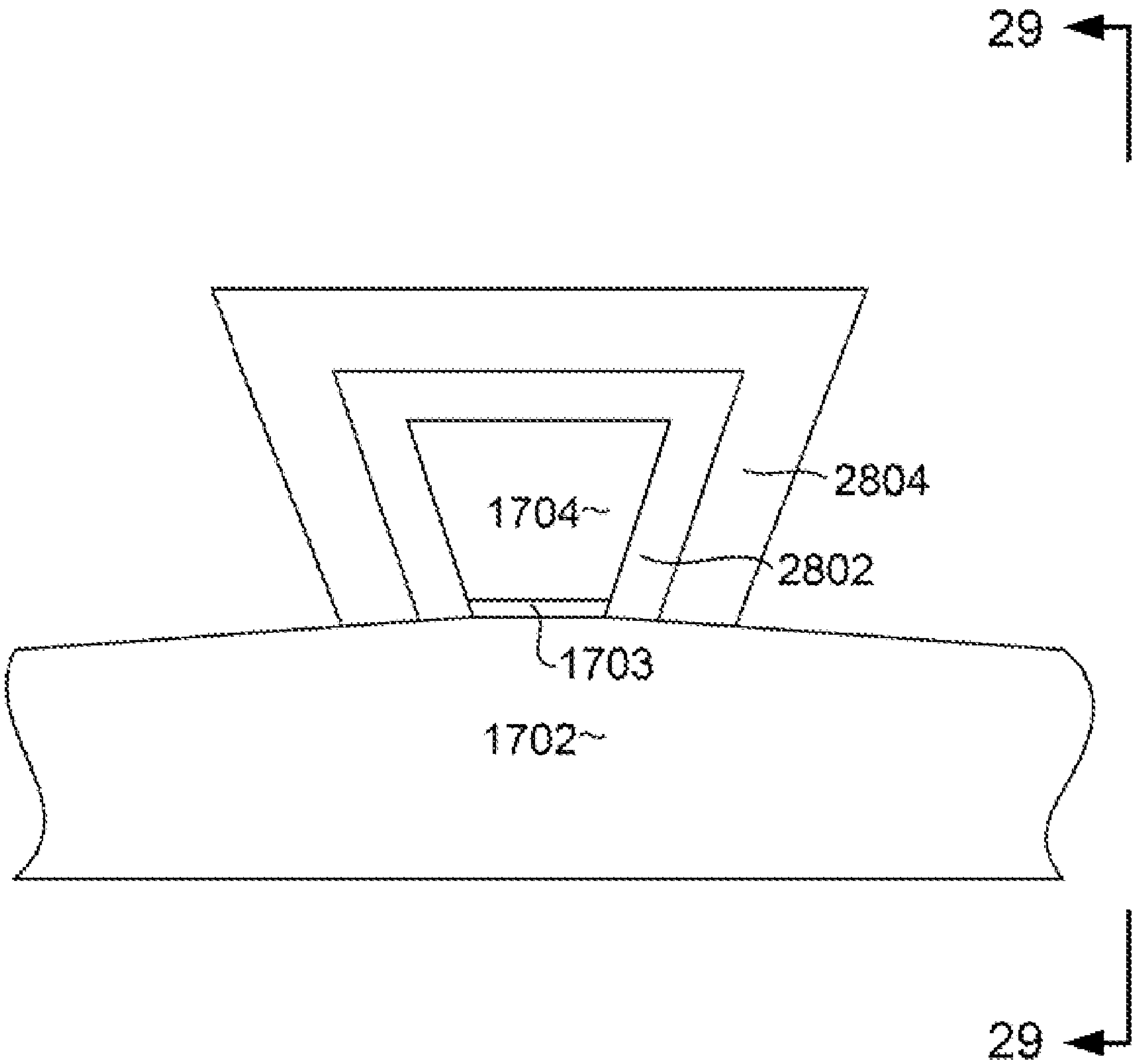
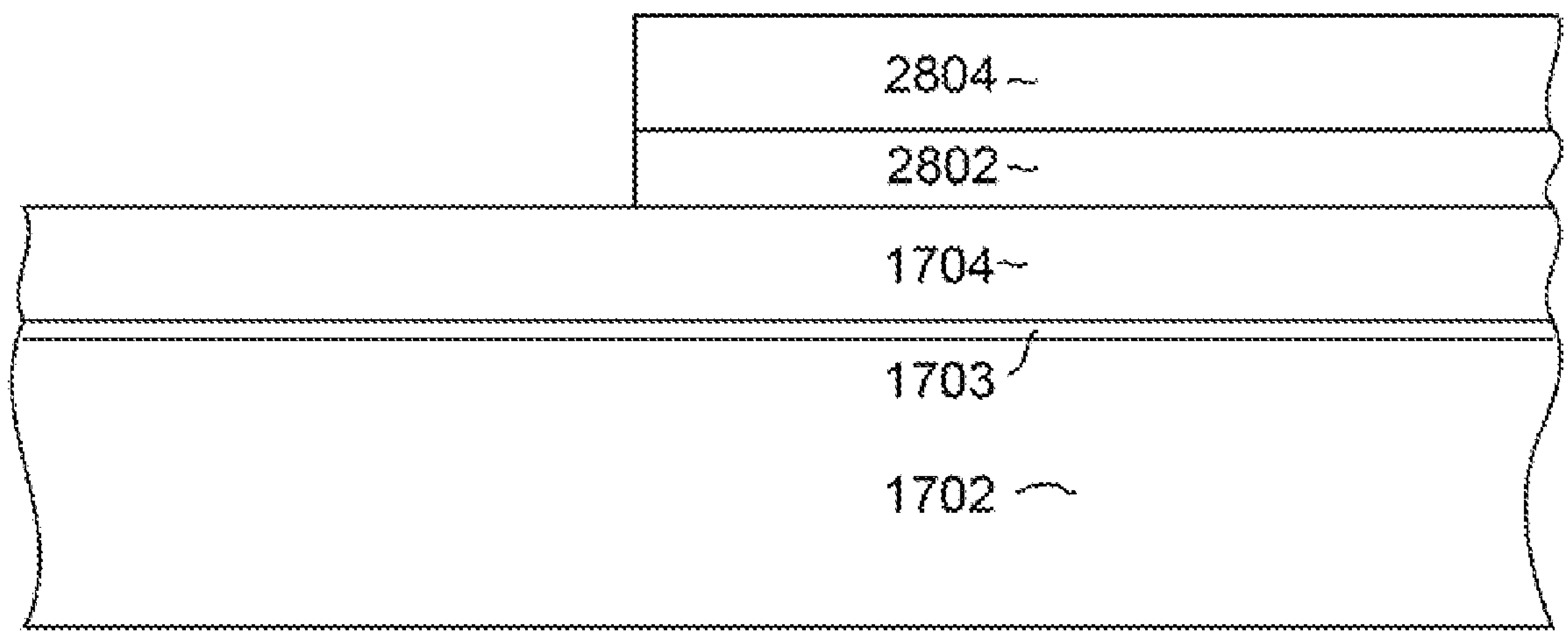


FIG. 28



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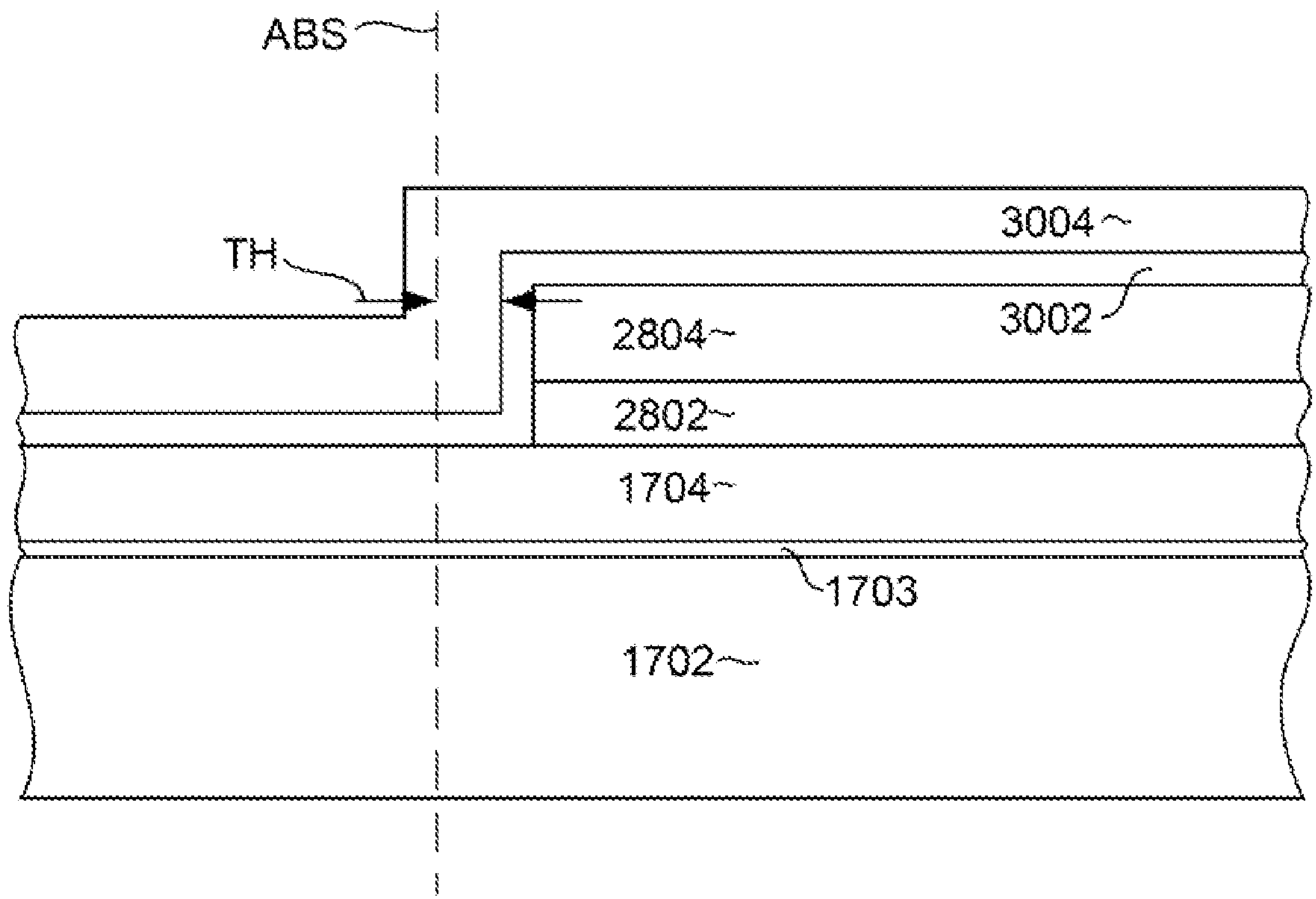

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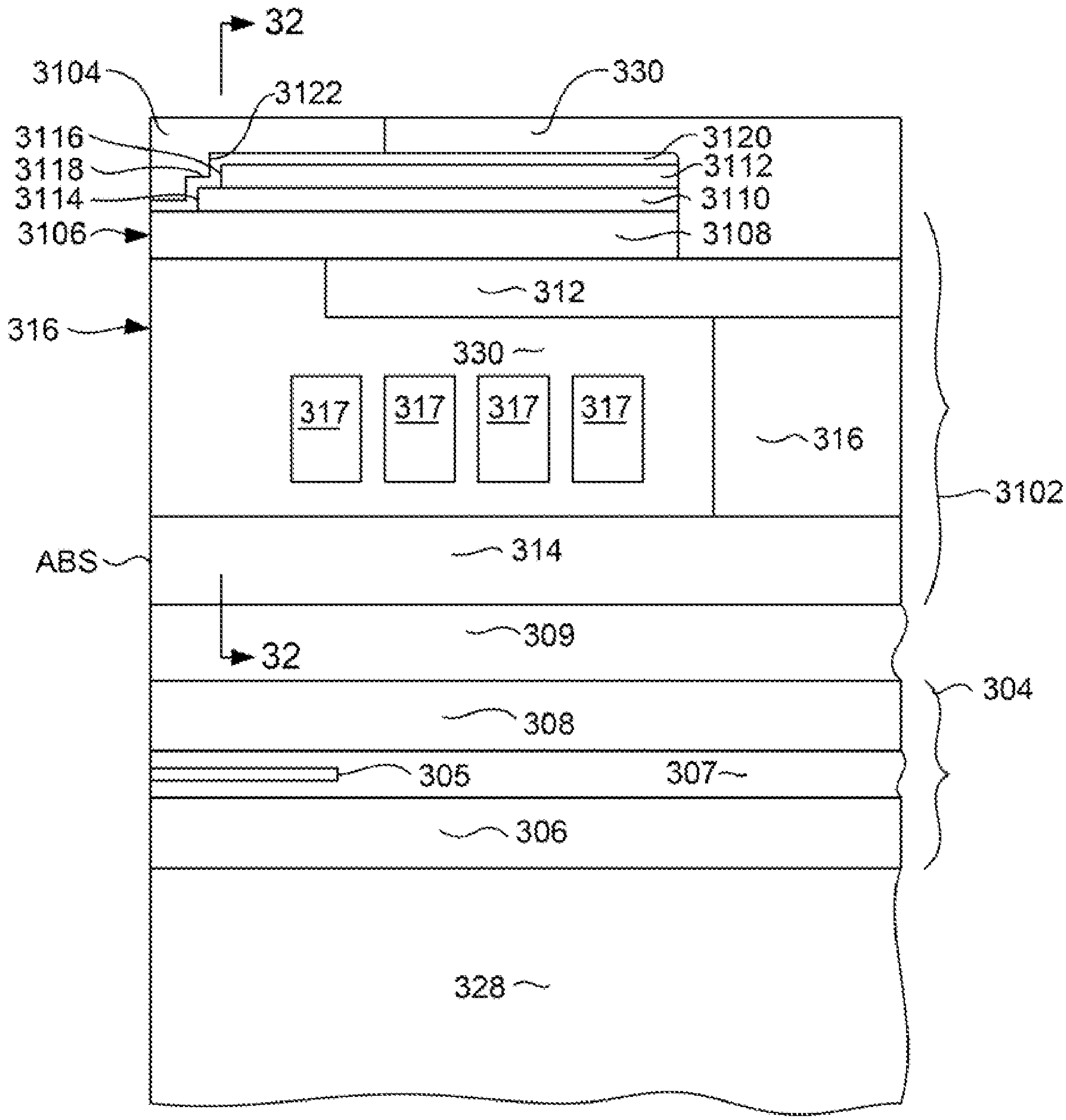
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FIG. 31

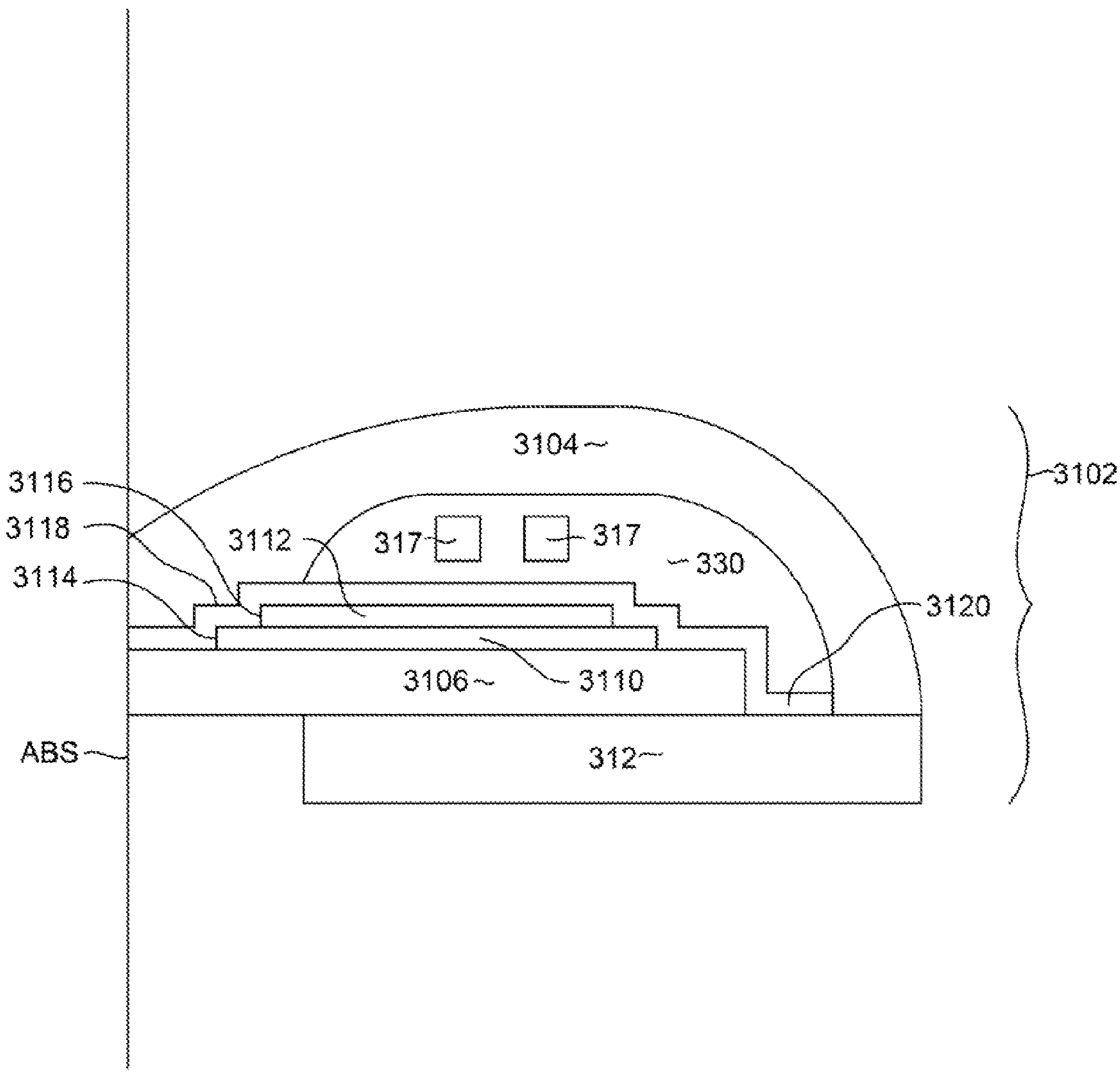
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FIG. 31A

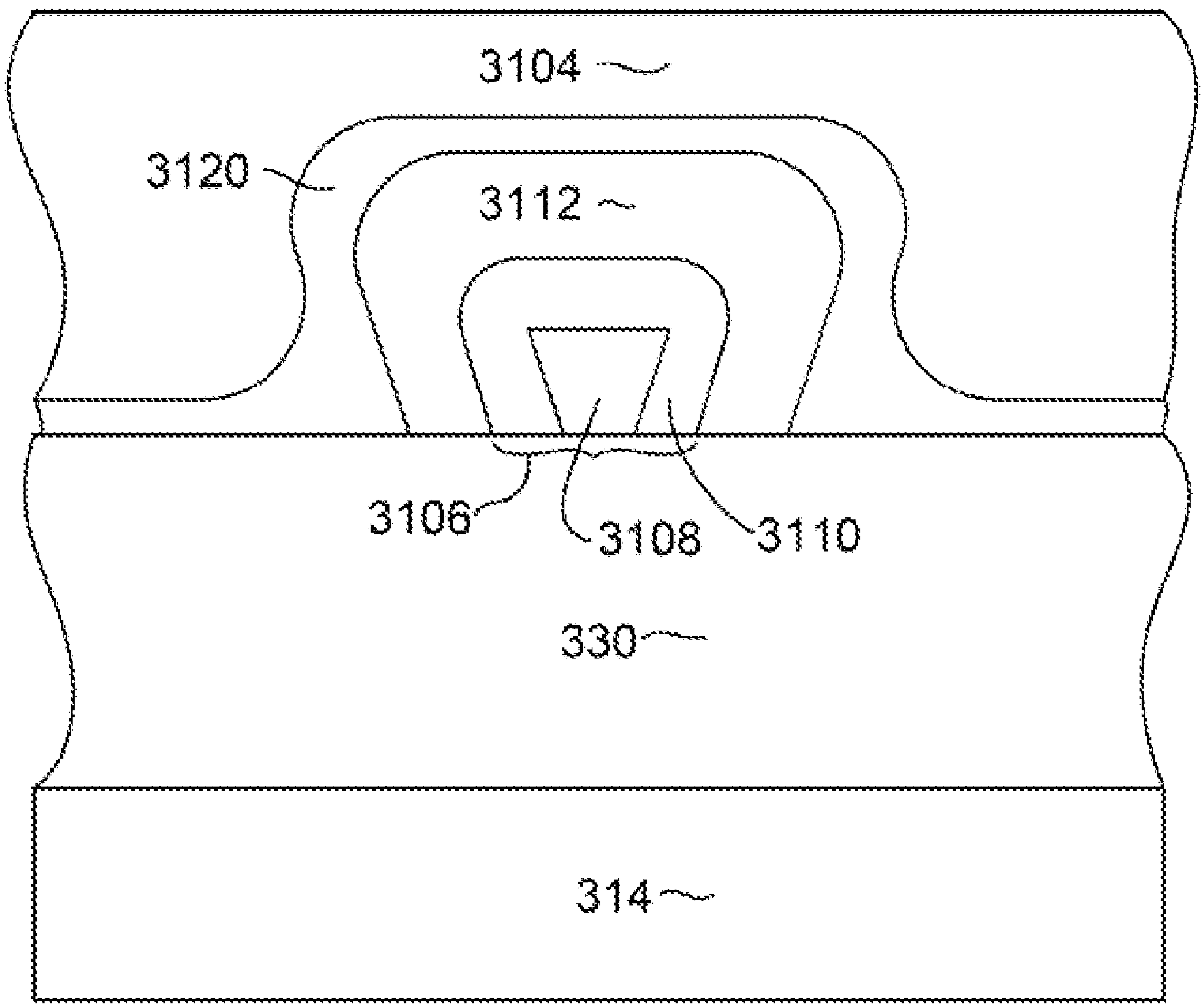


FIG. 32

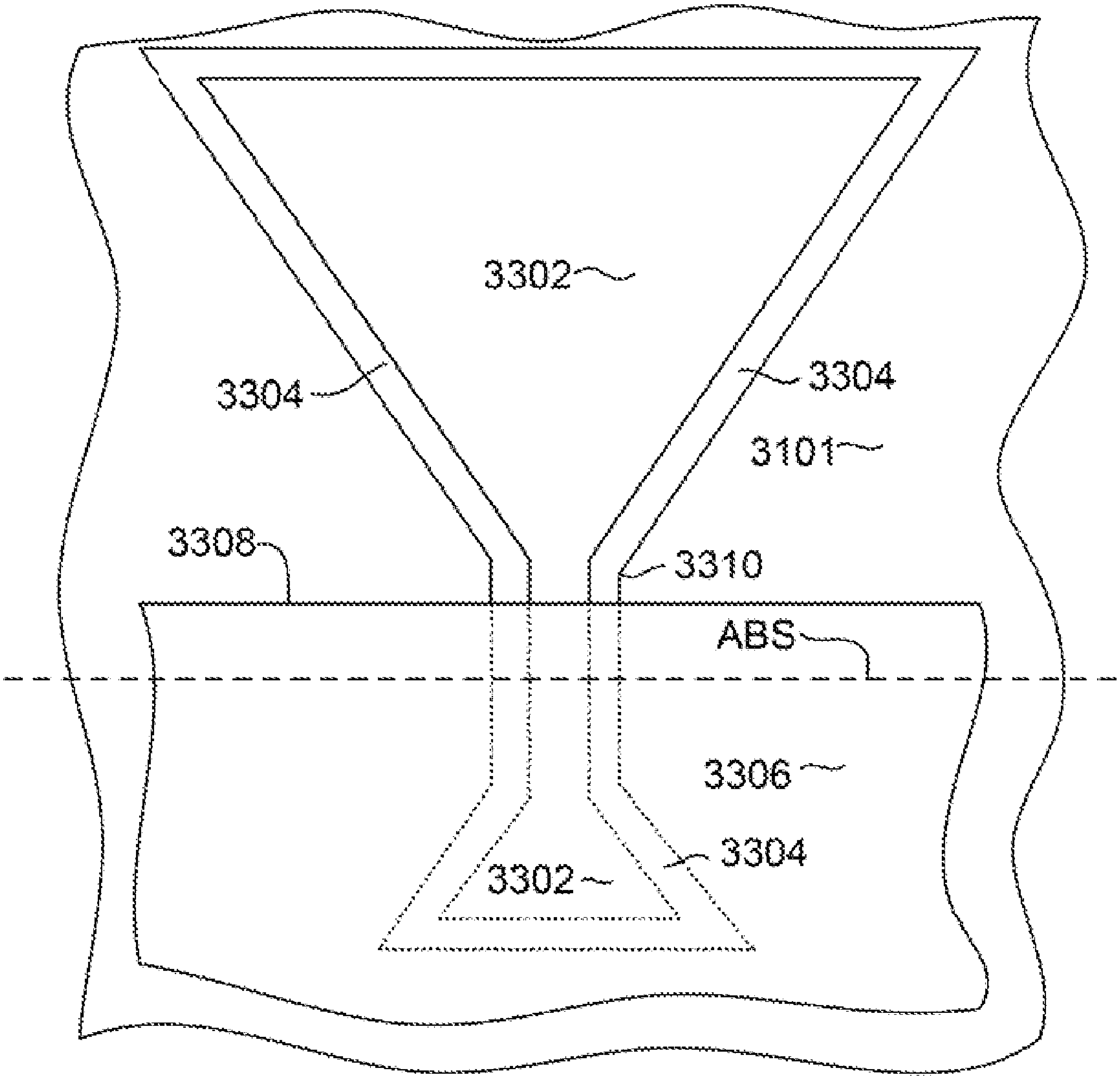


FIG. 33A

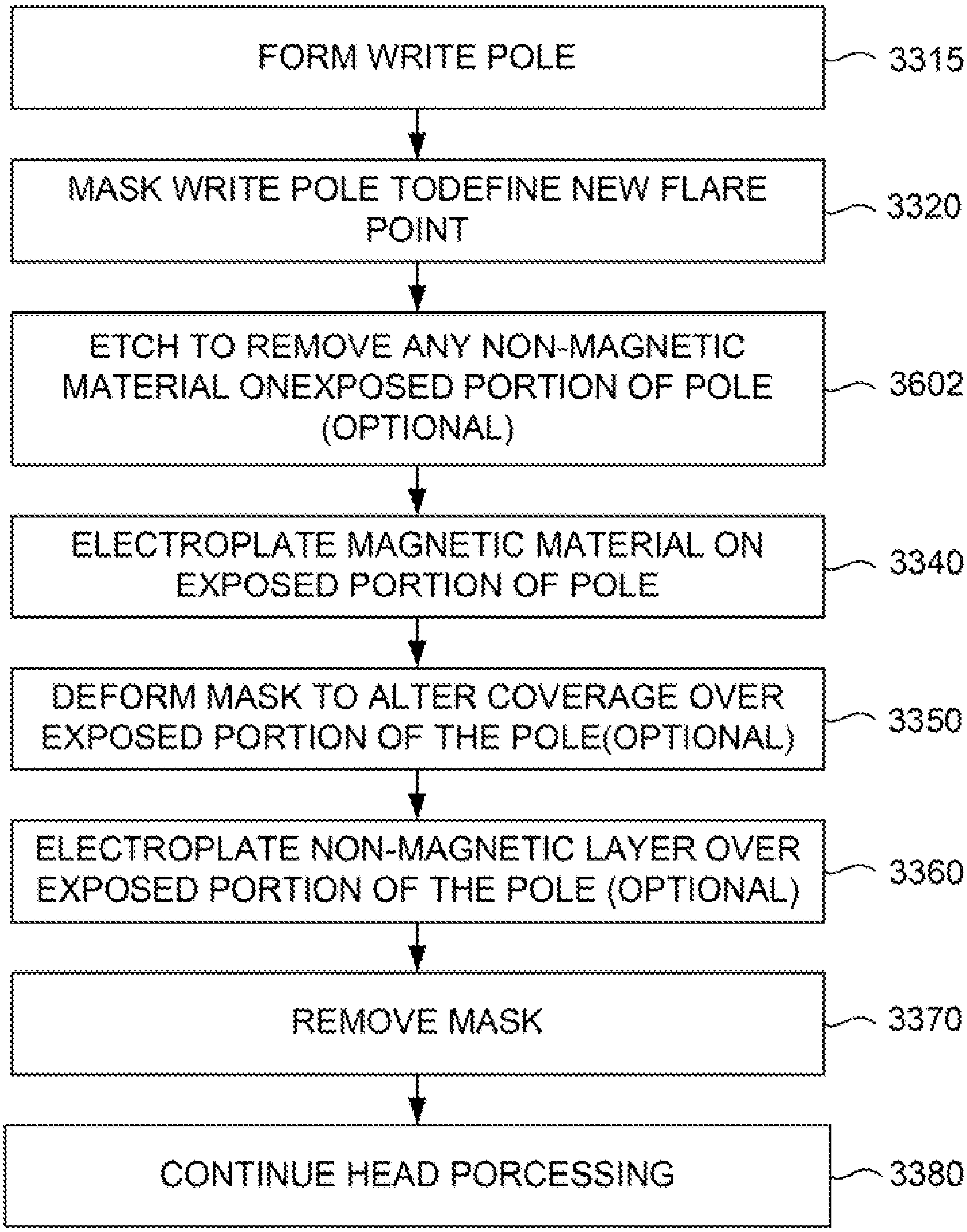

FORM WRITE POLE
3315
MASK WRITE POLE TODEFINE NEW FLARE POINT
3320
ETCH TO REMOVE ANY NON-MAGNETIC MATERIAL ONEXPOSED PORTION OF POLE (OPTIONAL)
3602
ELECTROPLATE MAGNETIC MATERIAL ON EXPOSED PORTION OF POLE
3340
DEFORM MASK TO ALTER COVERAGE OVER EXPOSED PORTION OF THE POLE(OPTIONAL)
3350
ELECTROPLATE NON-MAGNETIC LAYER OVER EXPOSED PORTION OF THE POLE (OPTIONAL)
3360
REMOVE MASK
3370
CONTINUE HEAD PORCESSING
3380

FIG. 33B

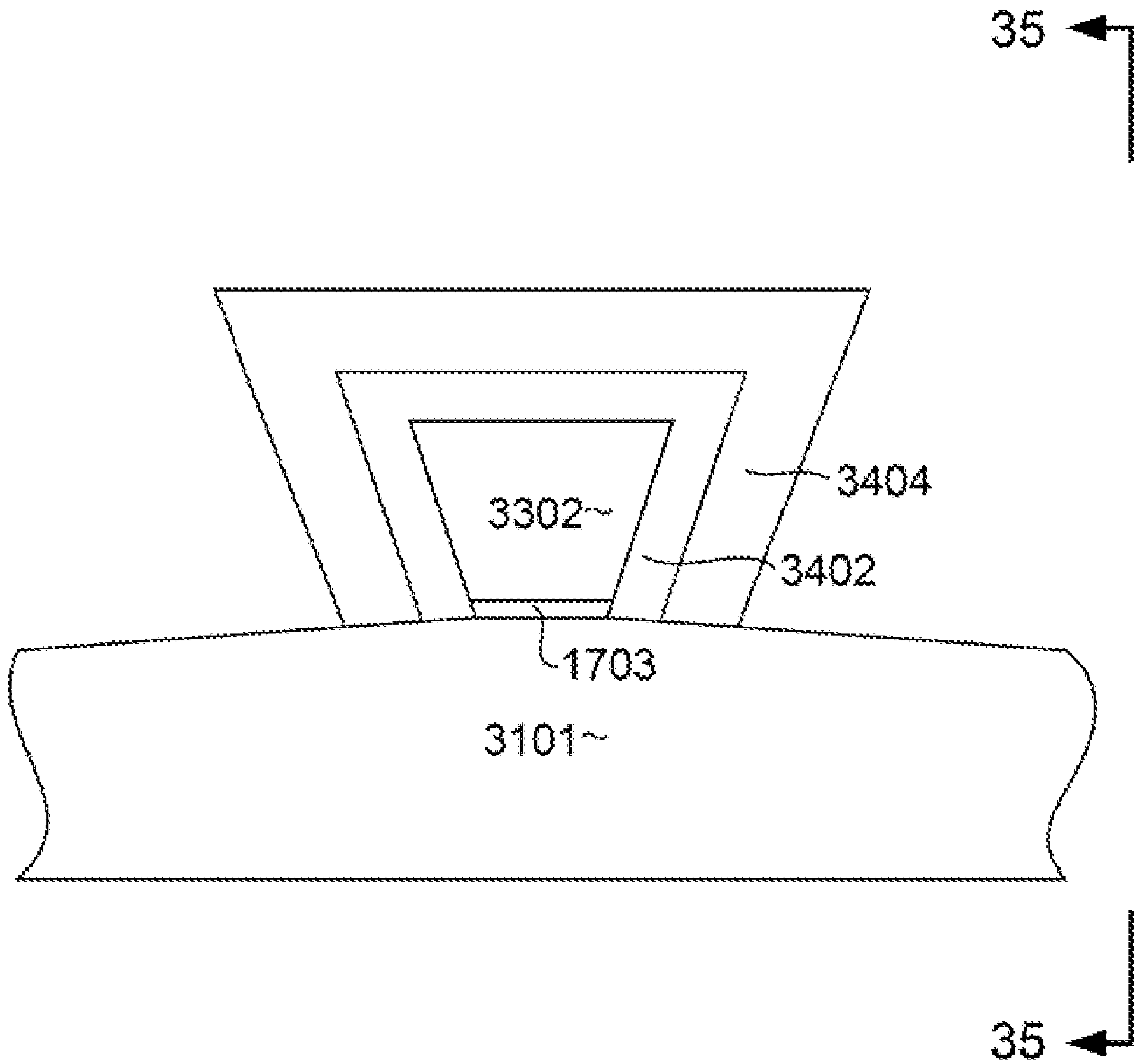


FIG. 34

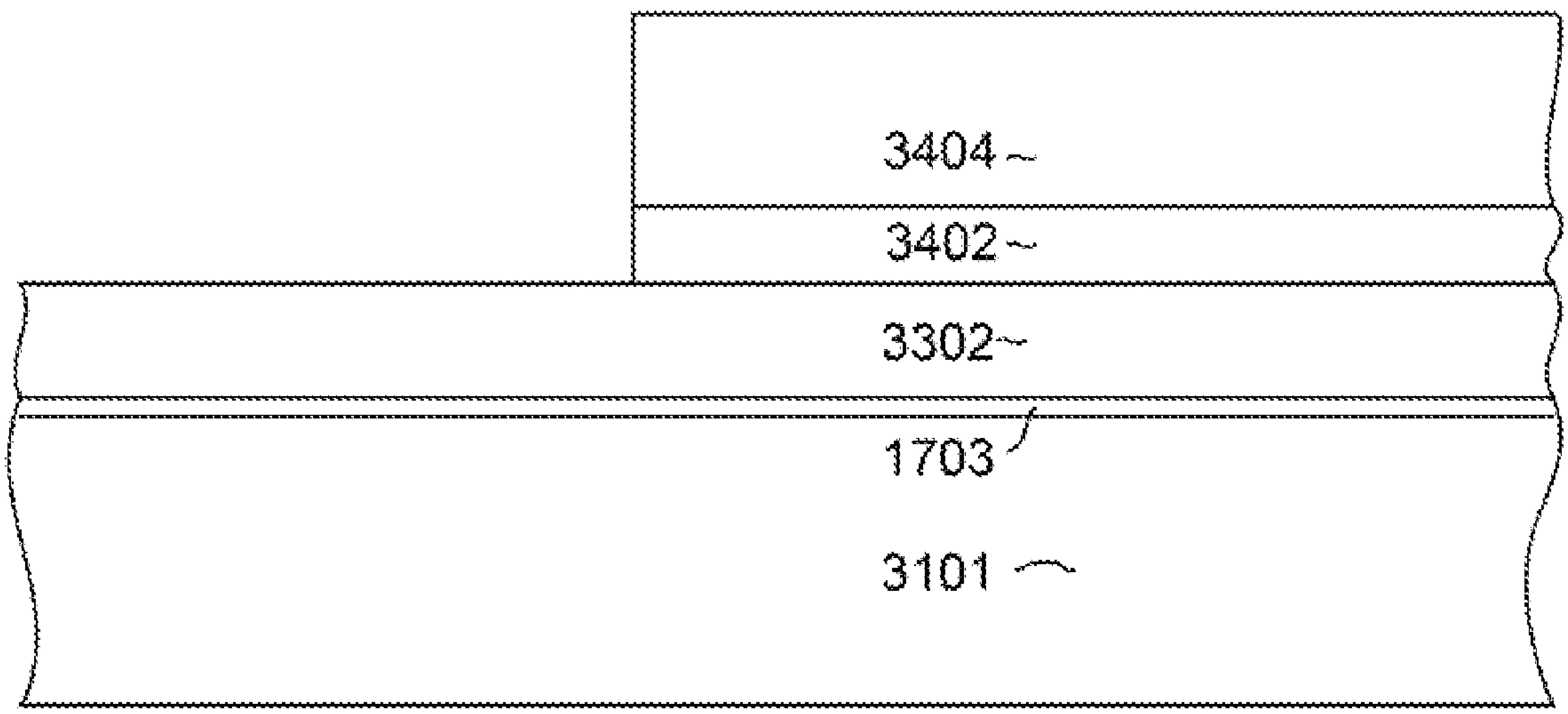


FIG. 35A

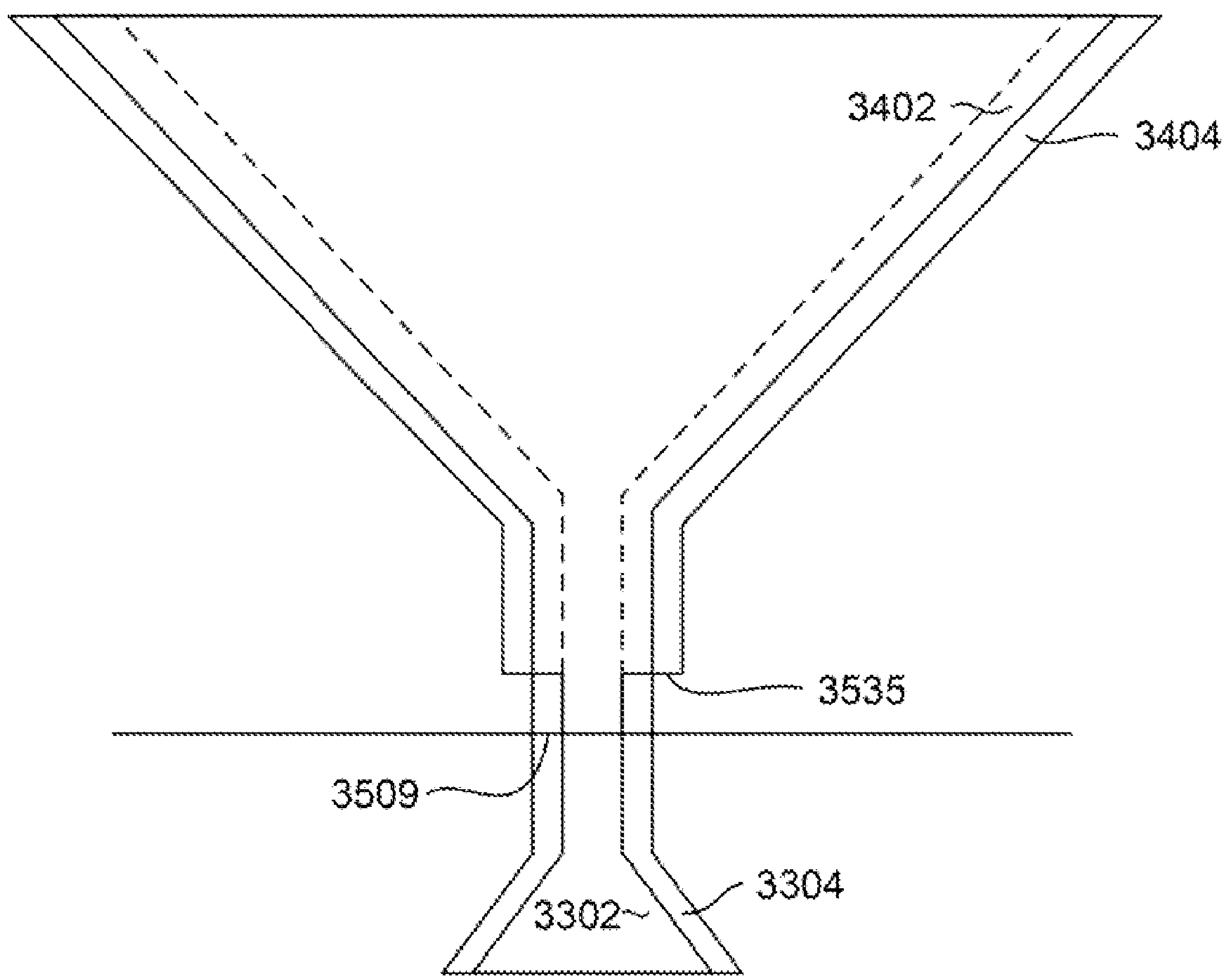


FIG. 35B

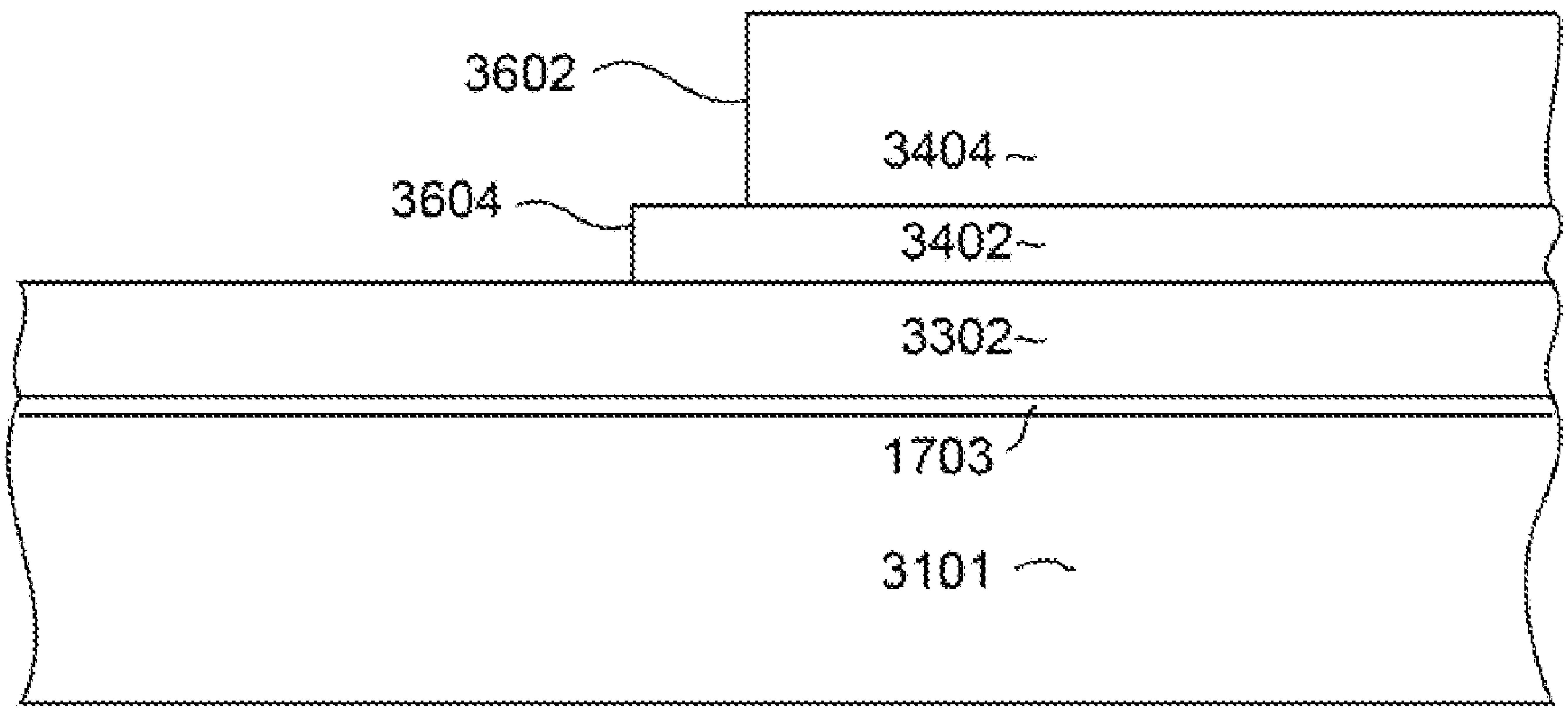


FIG. 36

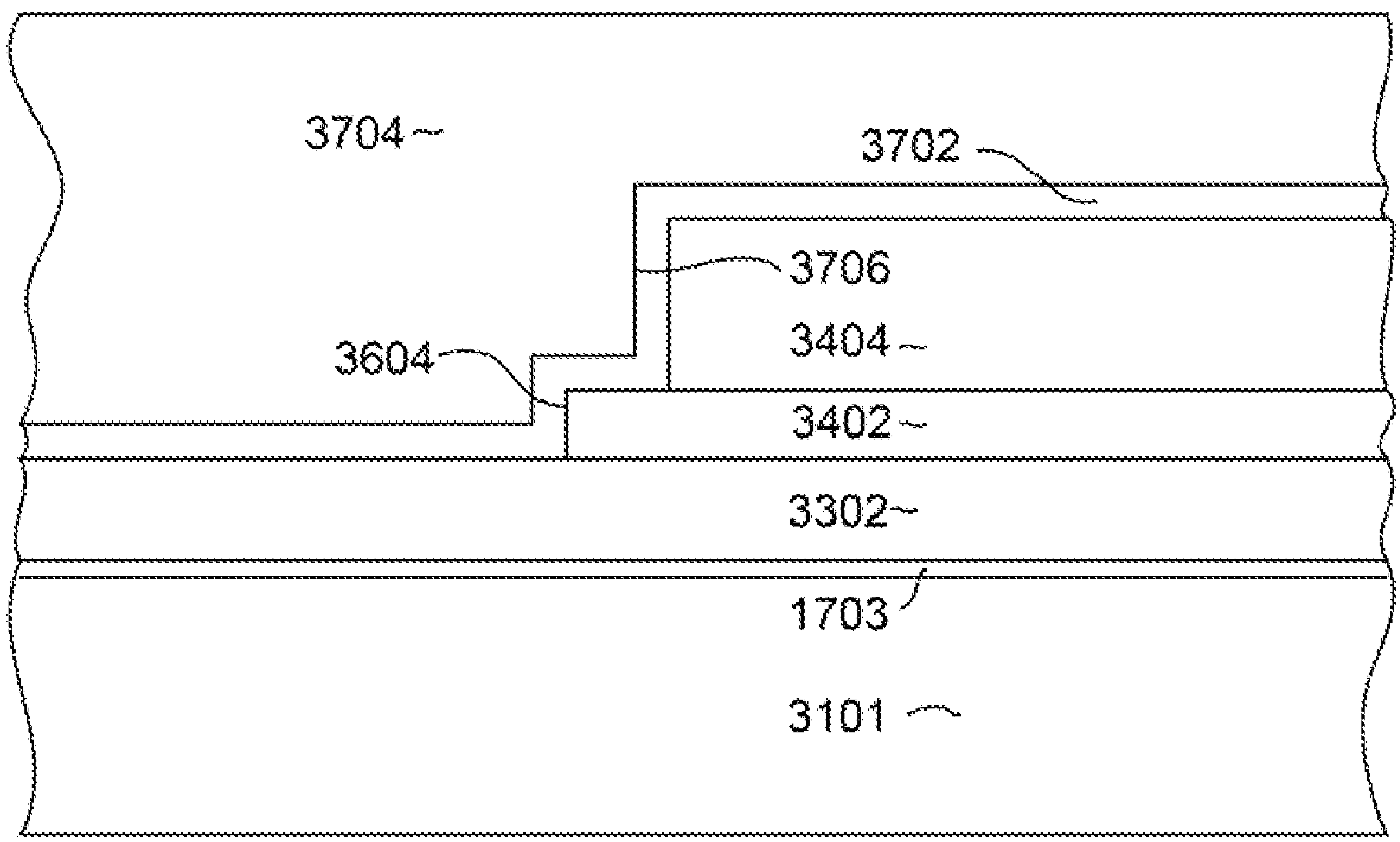


FIG. 37

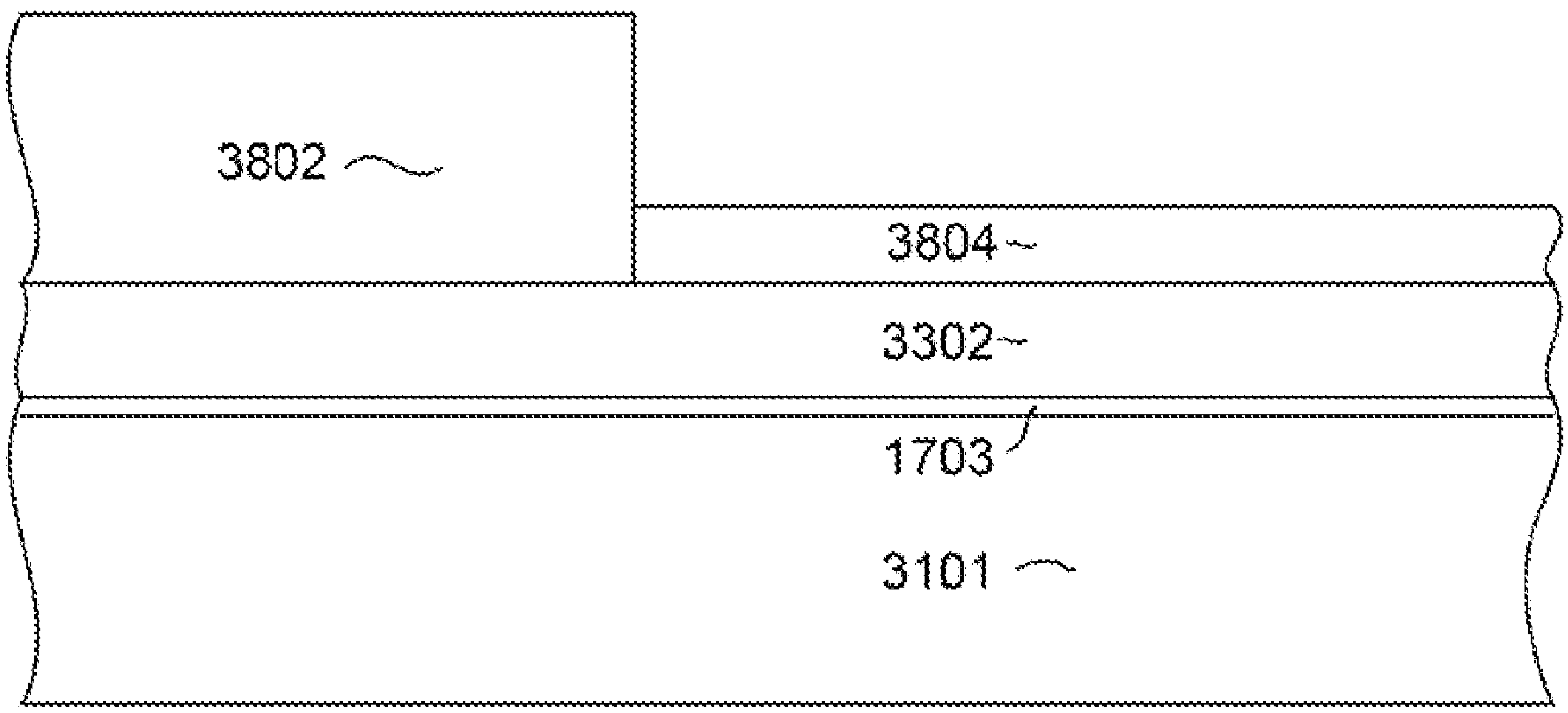


FIG. 38

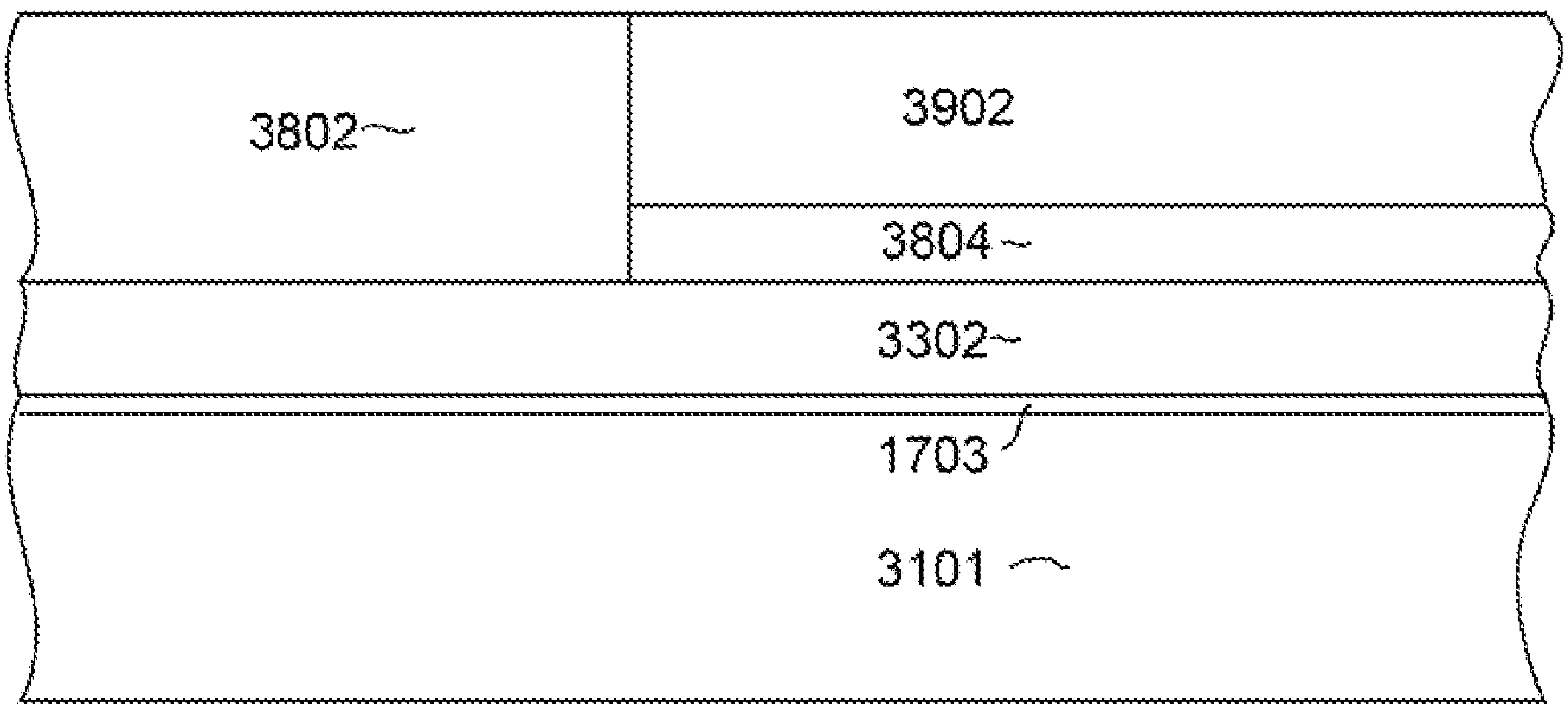


FIG. 39

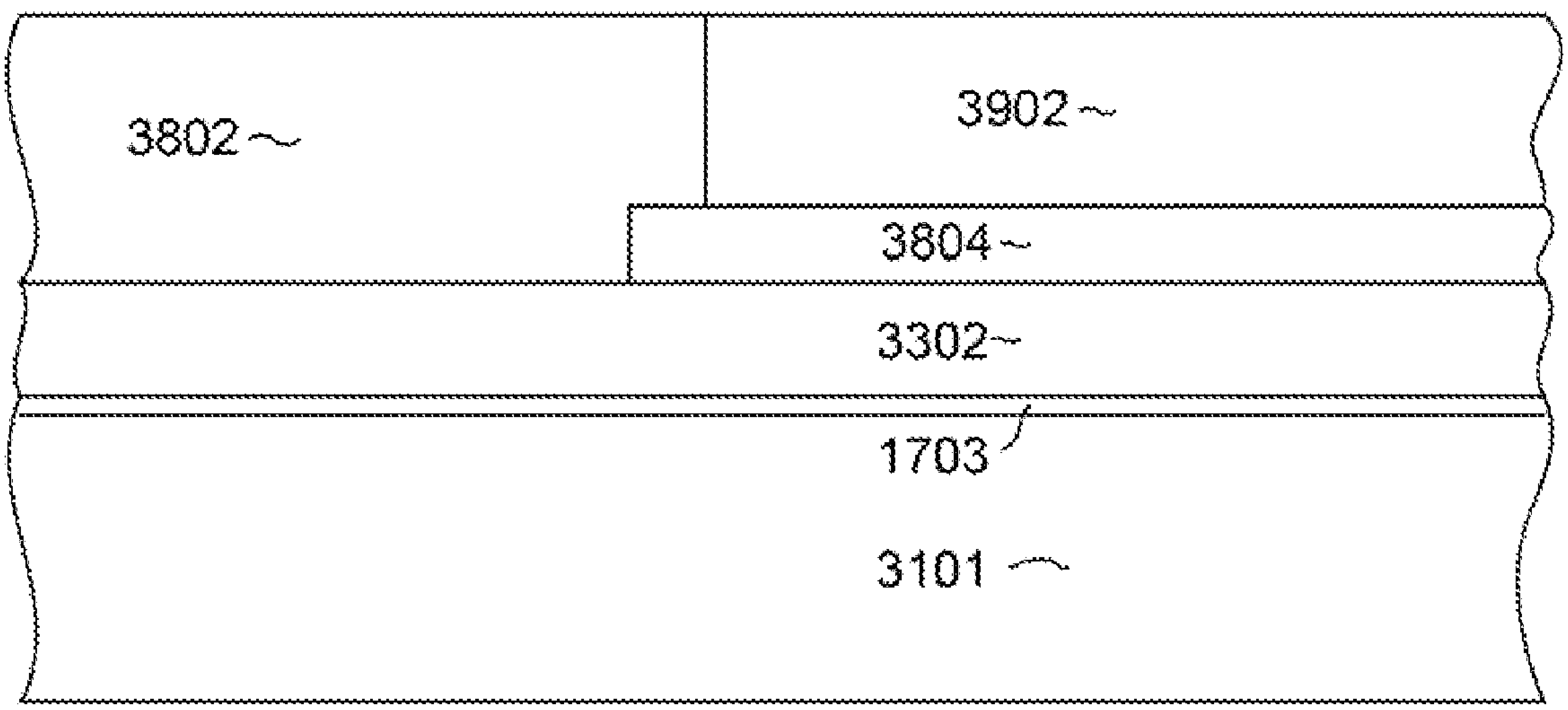


FIG. 40

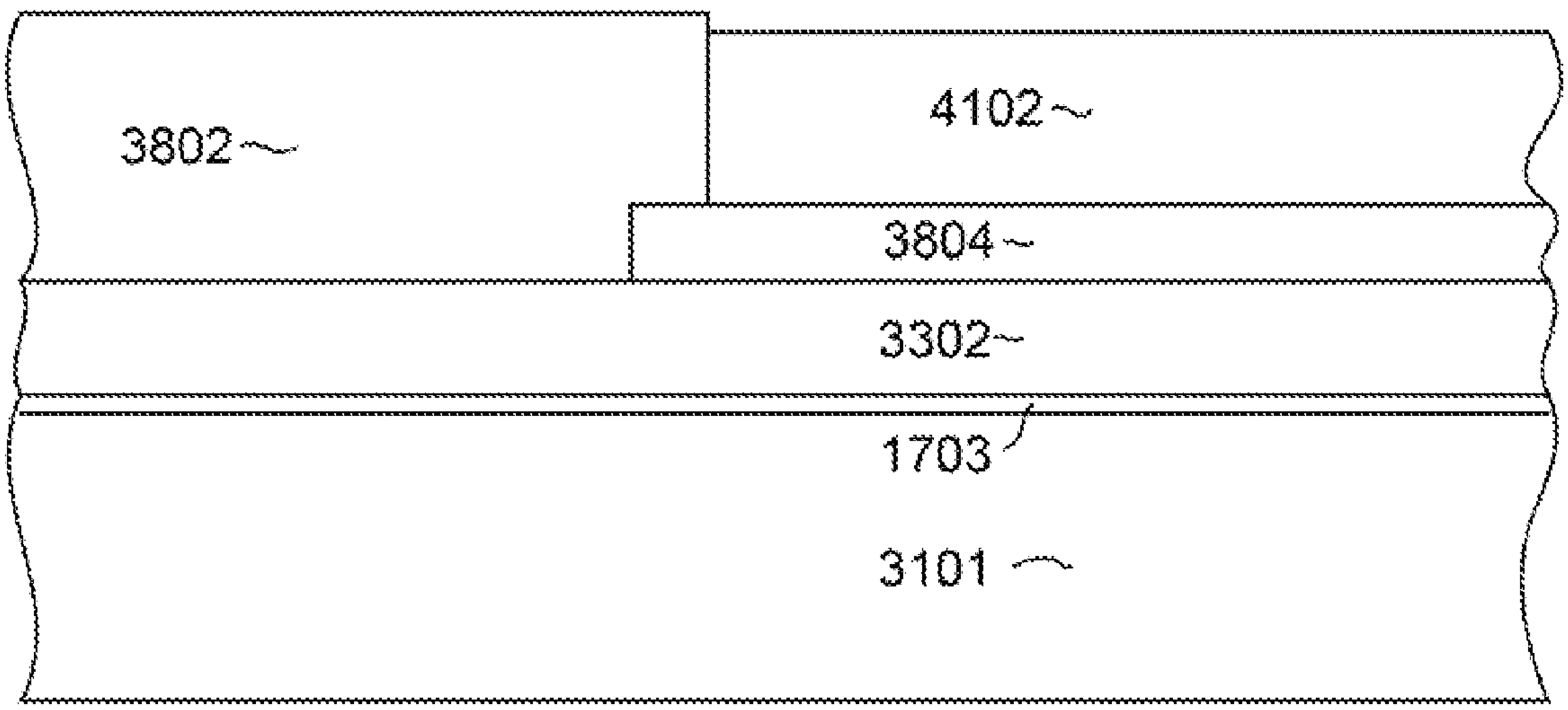


FIG. 41A

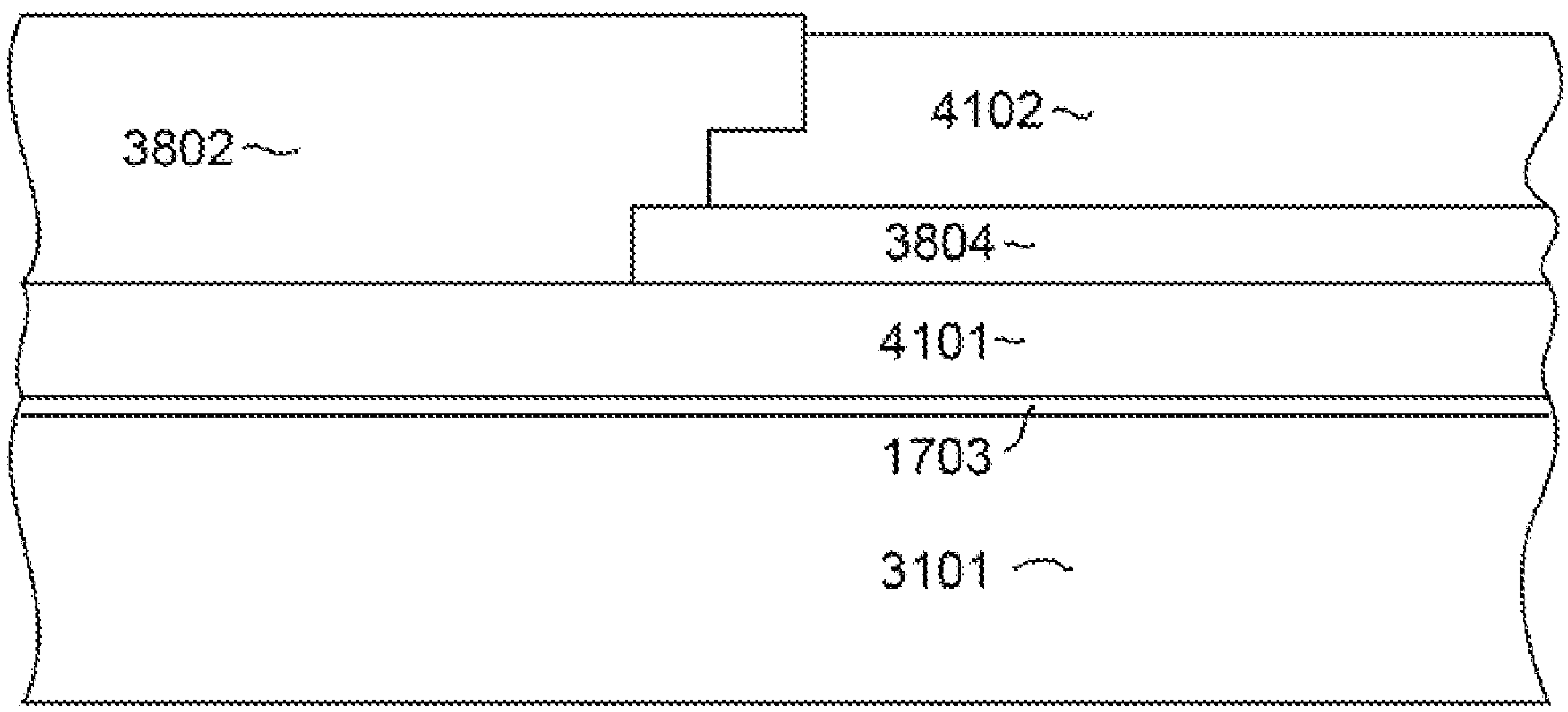


FIG. 41B

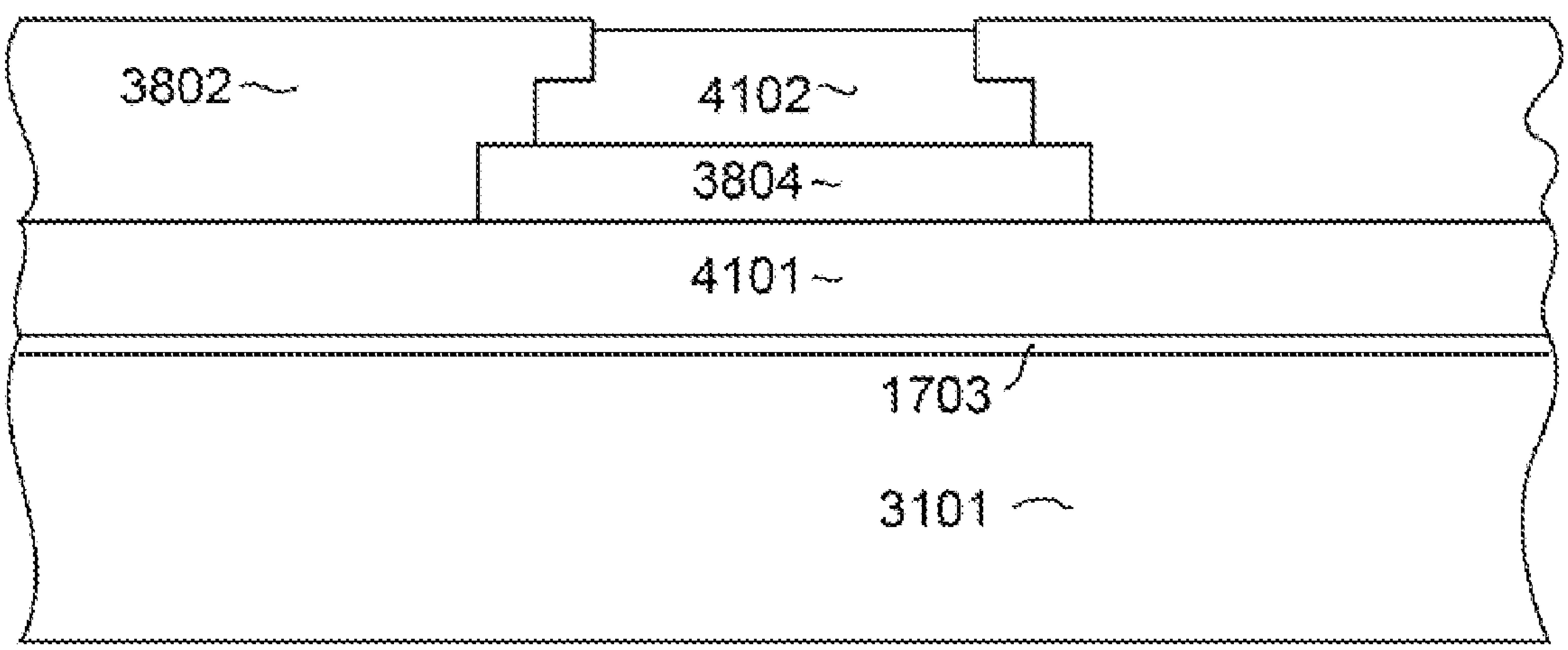


FIG. 41C

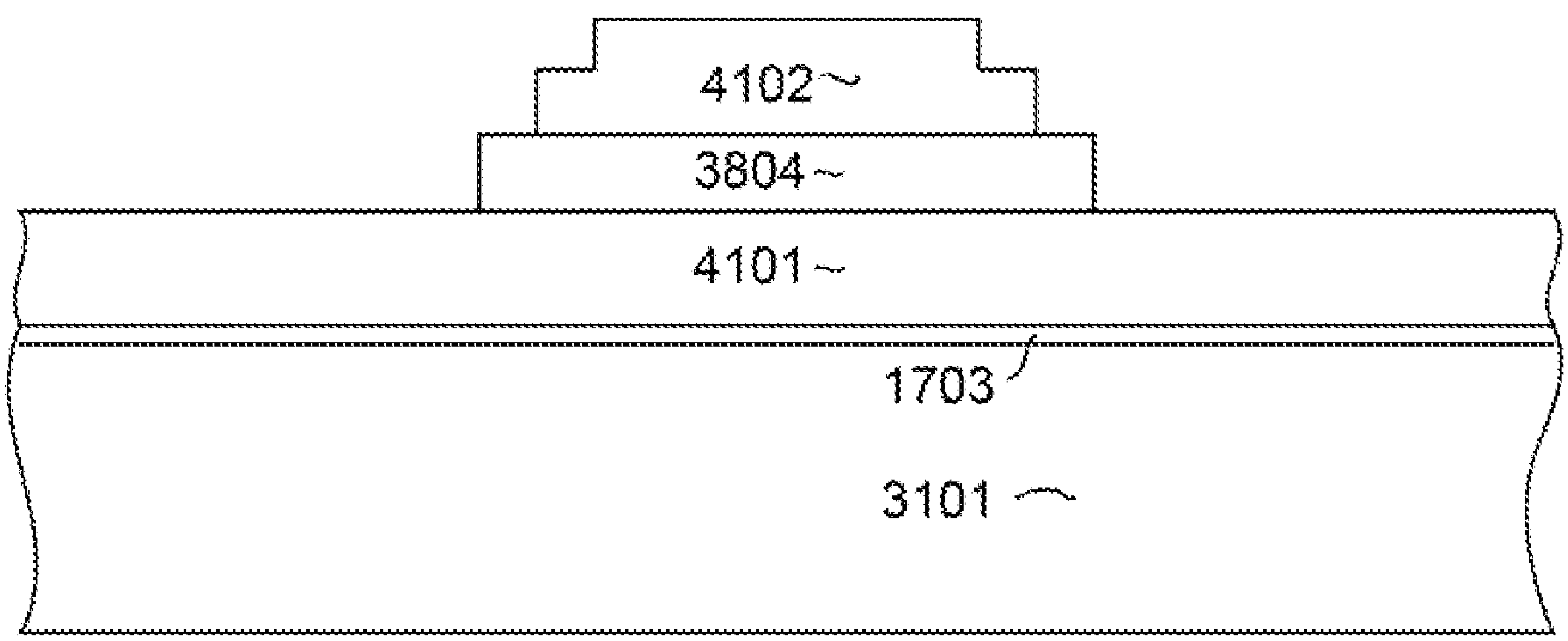


FIG. 41D

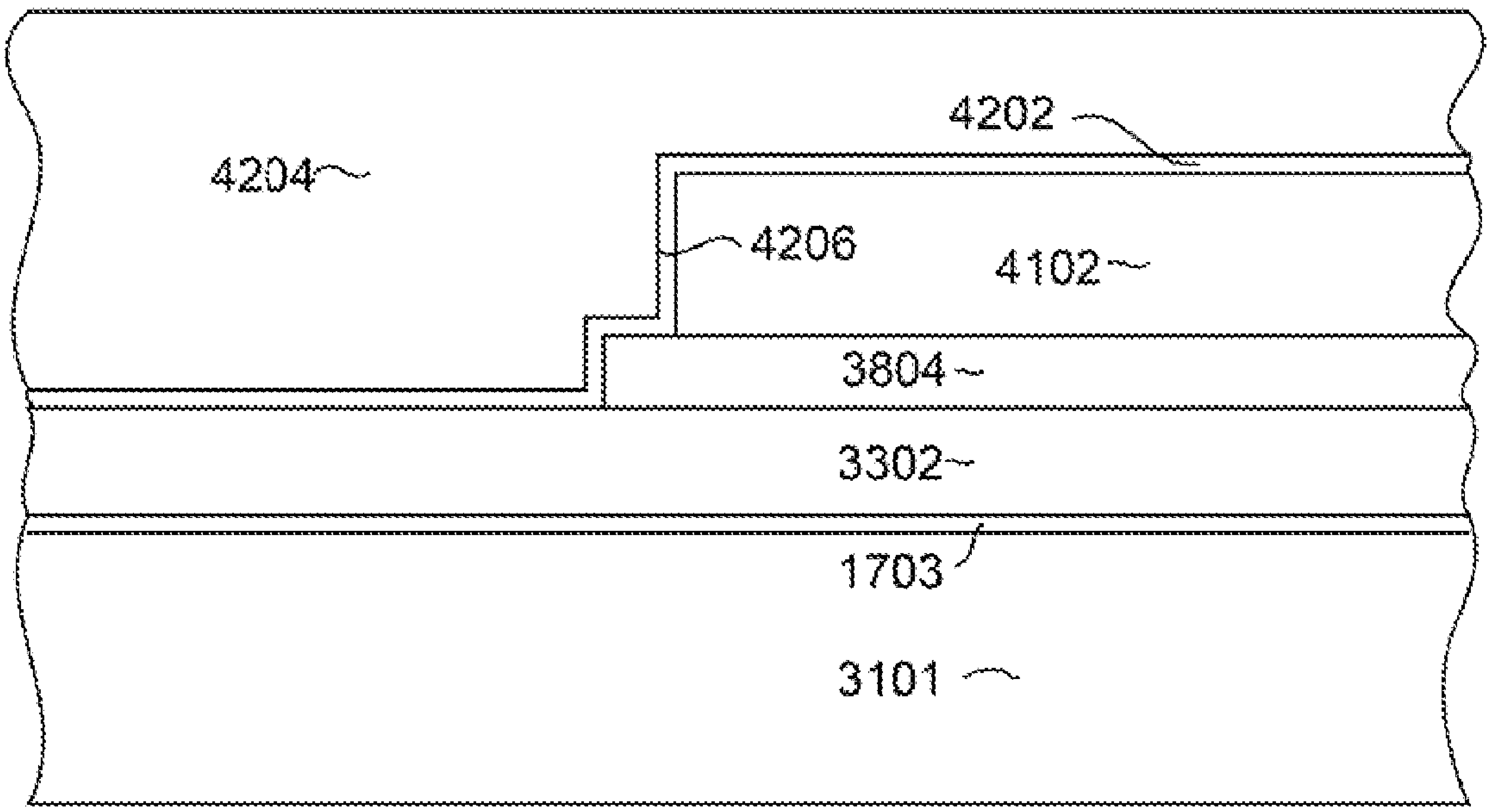
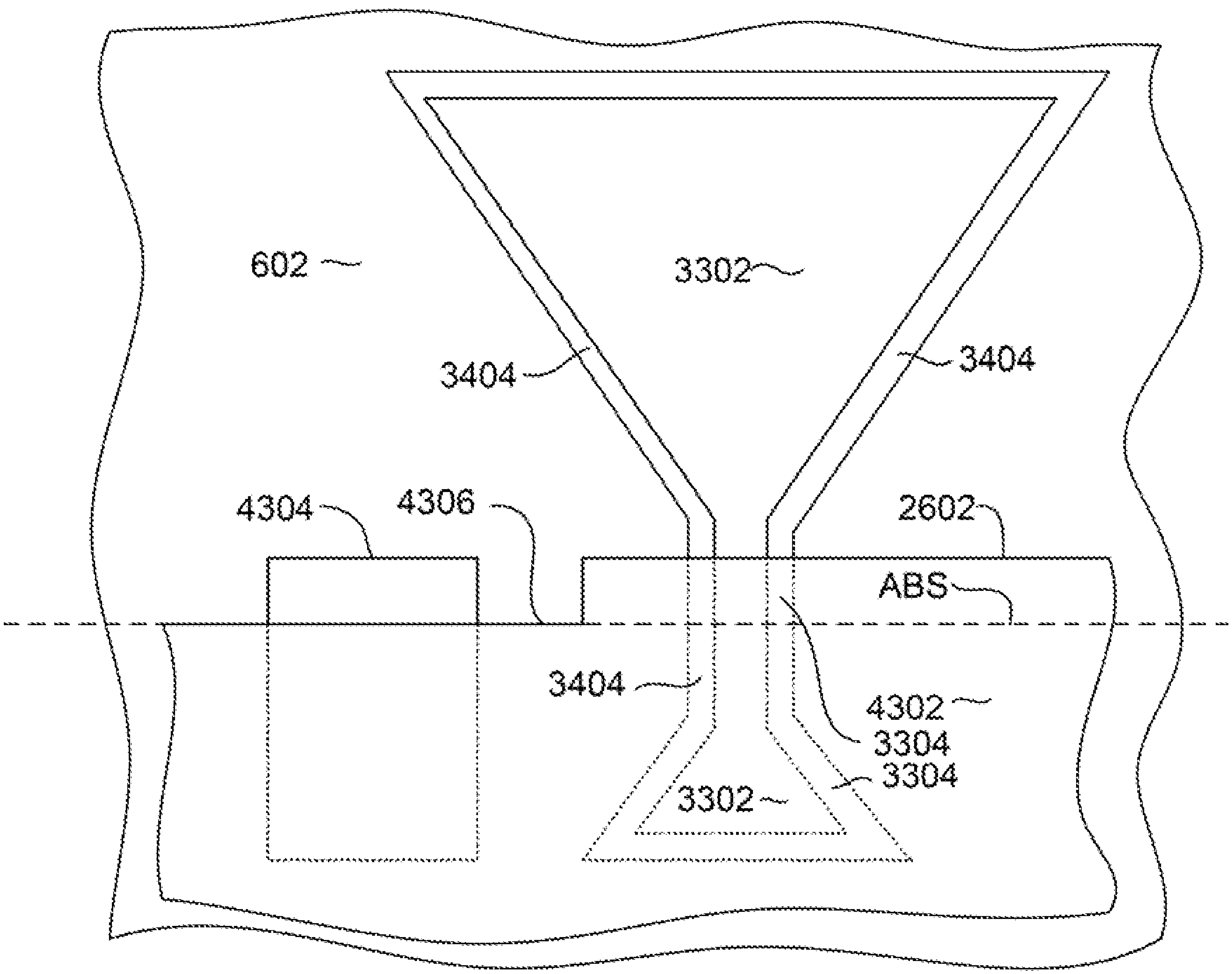


FIG. 42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3302

FIG. 43

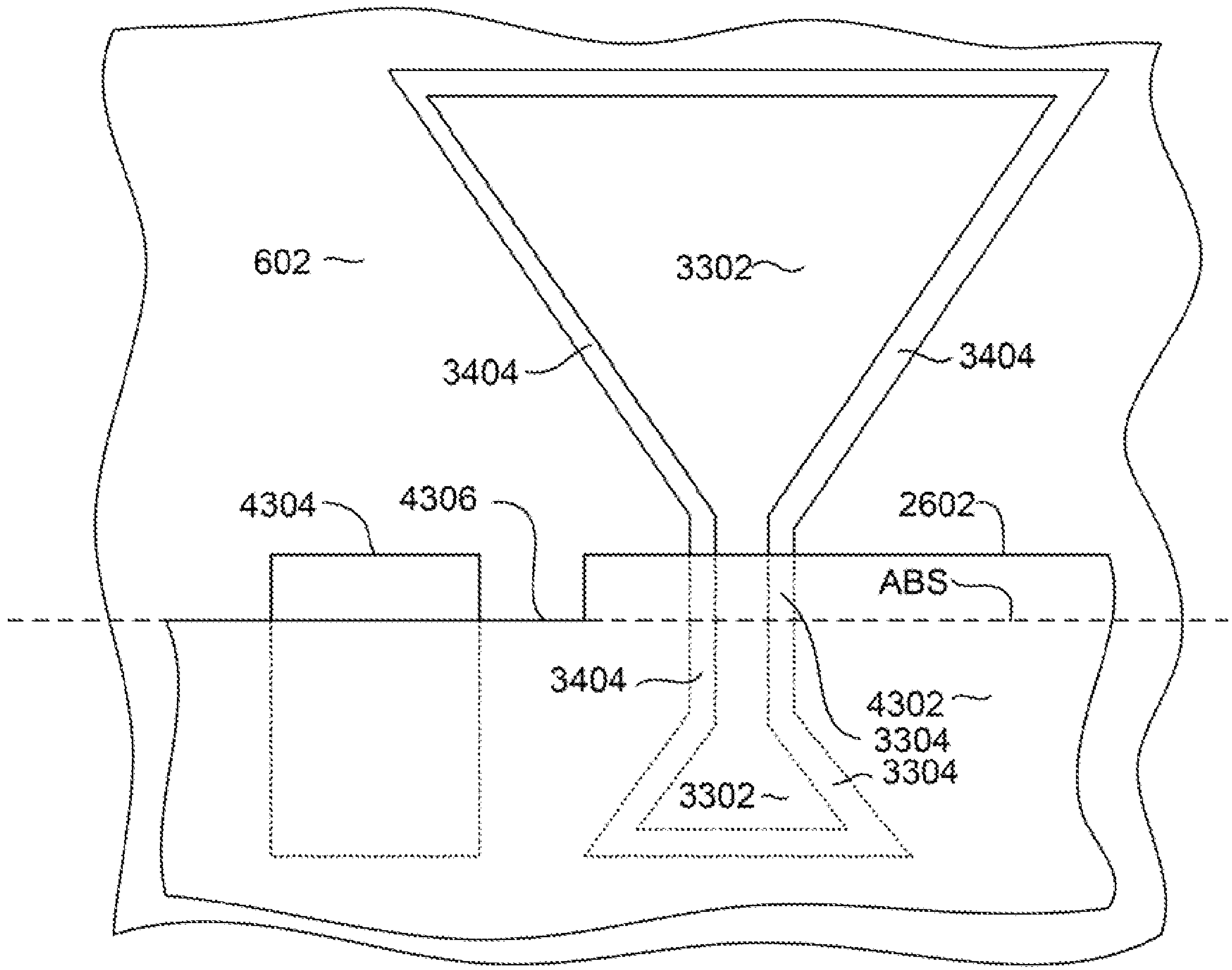
602
3302
3404
3404
4304
4306
2602
ABS
3404
4302
3304
3304
3302

FIG. 43A

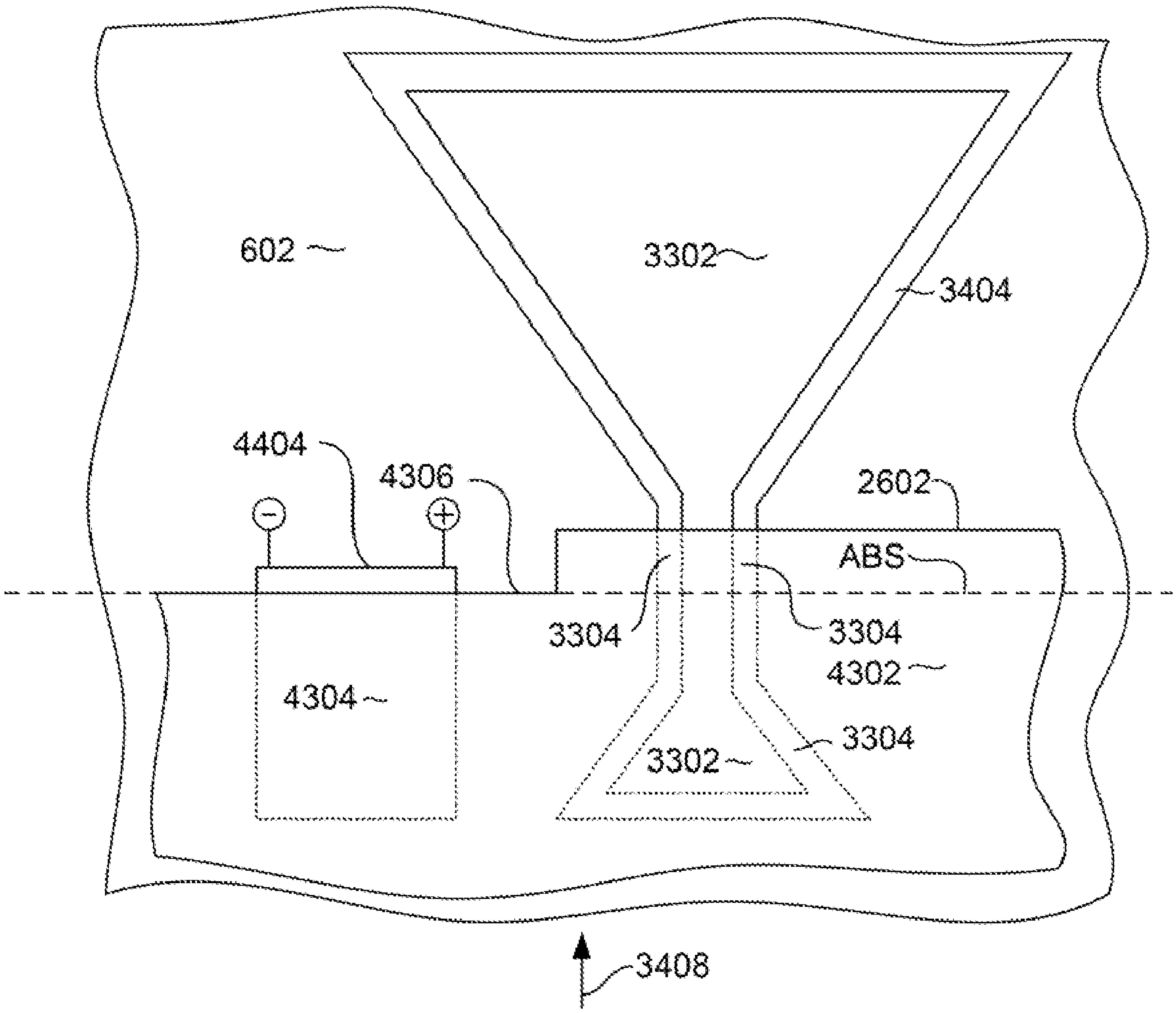
602
3302
3404
4404
4306
2602
ABS
3304
3304
4302
4304
3302
3304
3408

FIG. 44

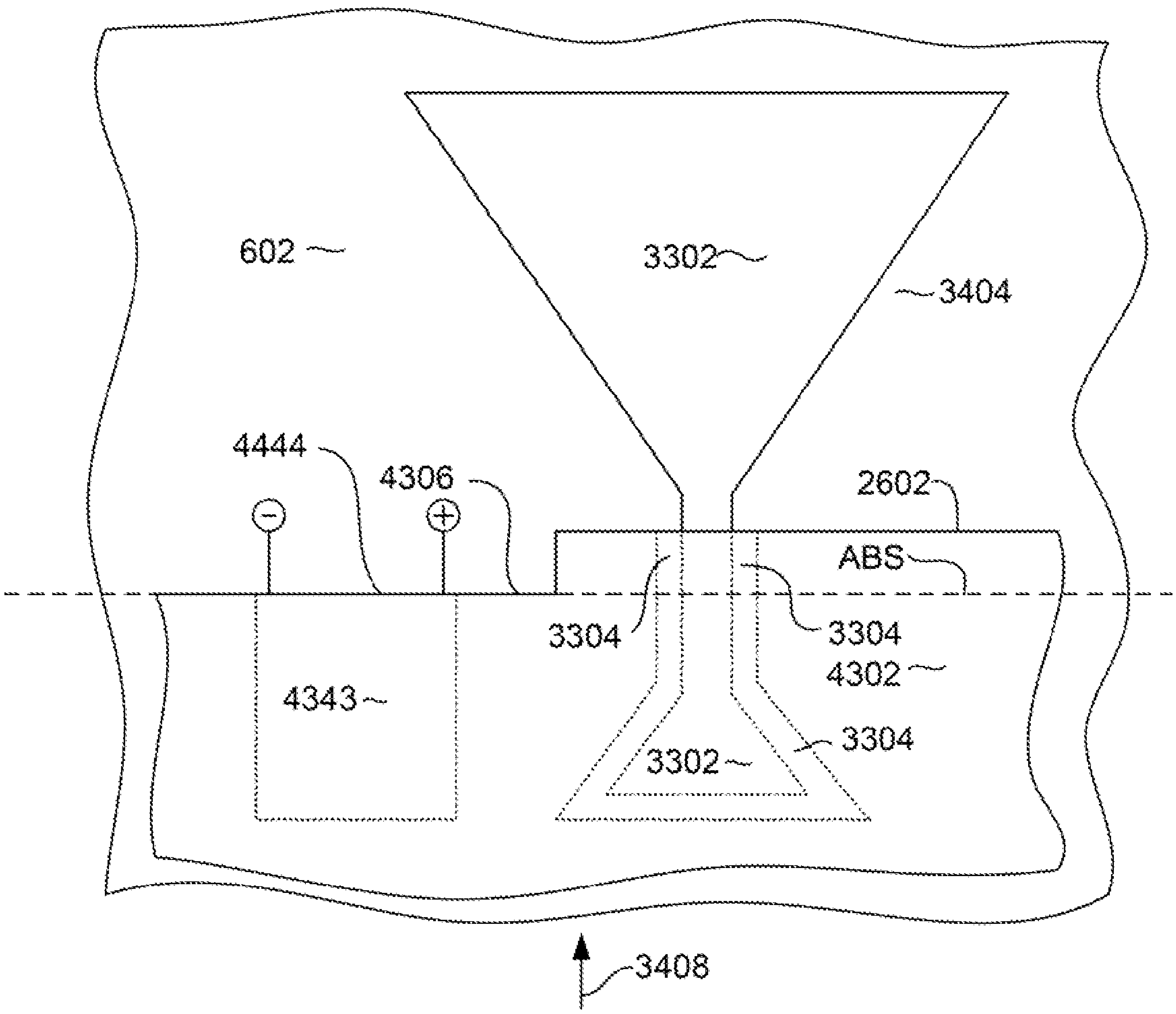
602
3302
3404
4444
4306
2602
ABS
3304
3304
4302
4343
3304
3302
3408

FIG. 44A

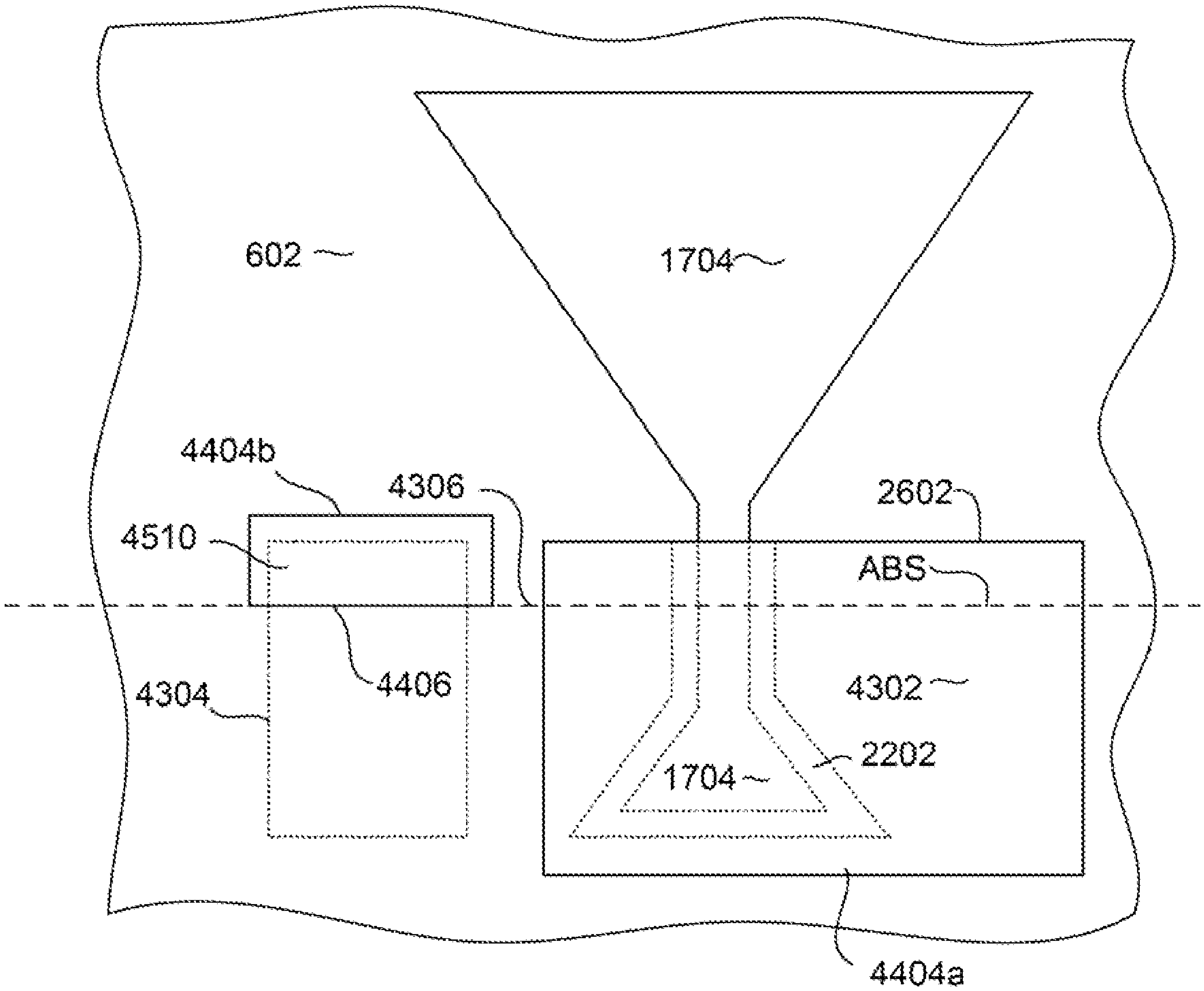
602
1704
4404b
4306
2602
4510
ABS
4304
4406
4302
2202
1704
4404a

FIG. 45

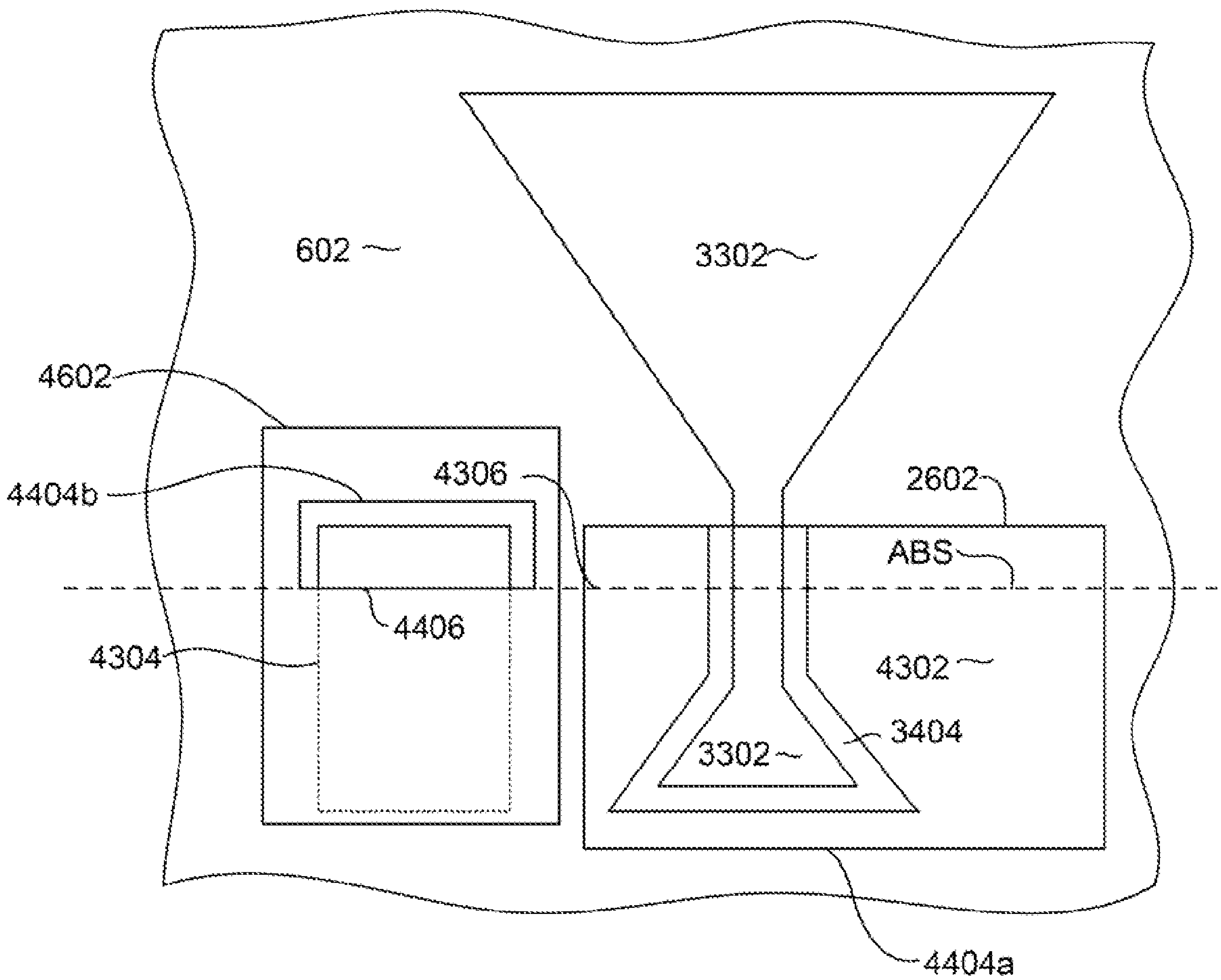
602
3302
4602
4306
2602
4404b
ABS
4406
4304
4302
3404
3302
4404a

FIG. 46

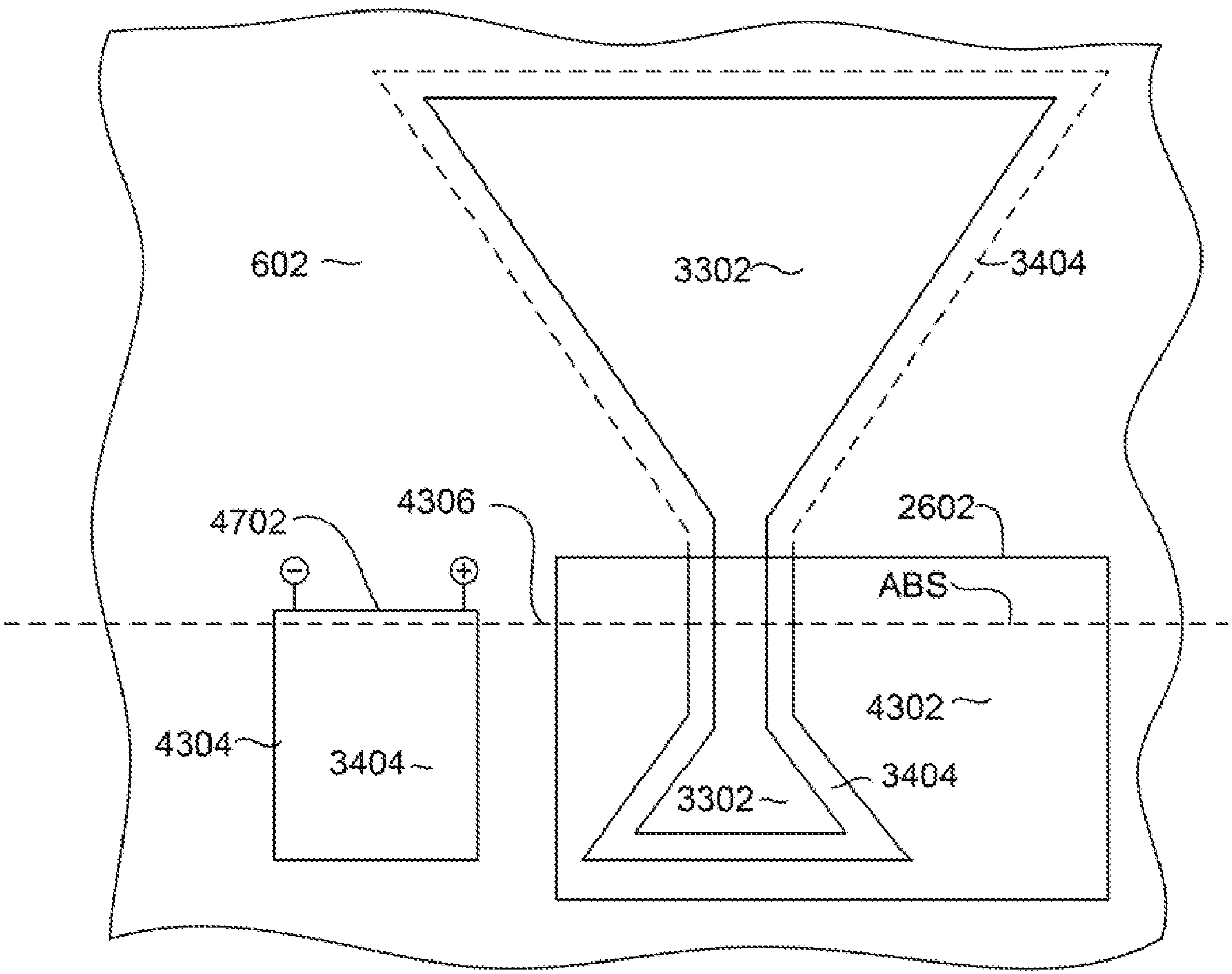

FIG. 47

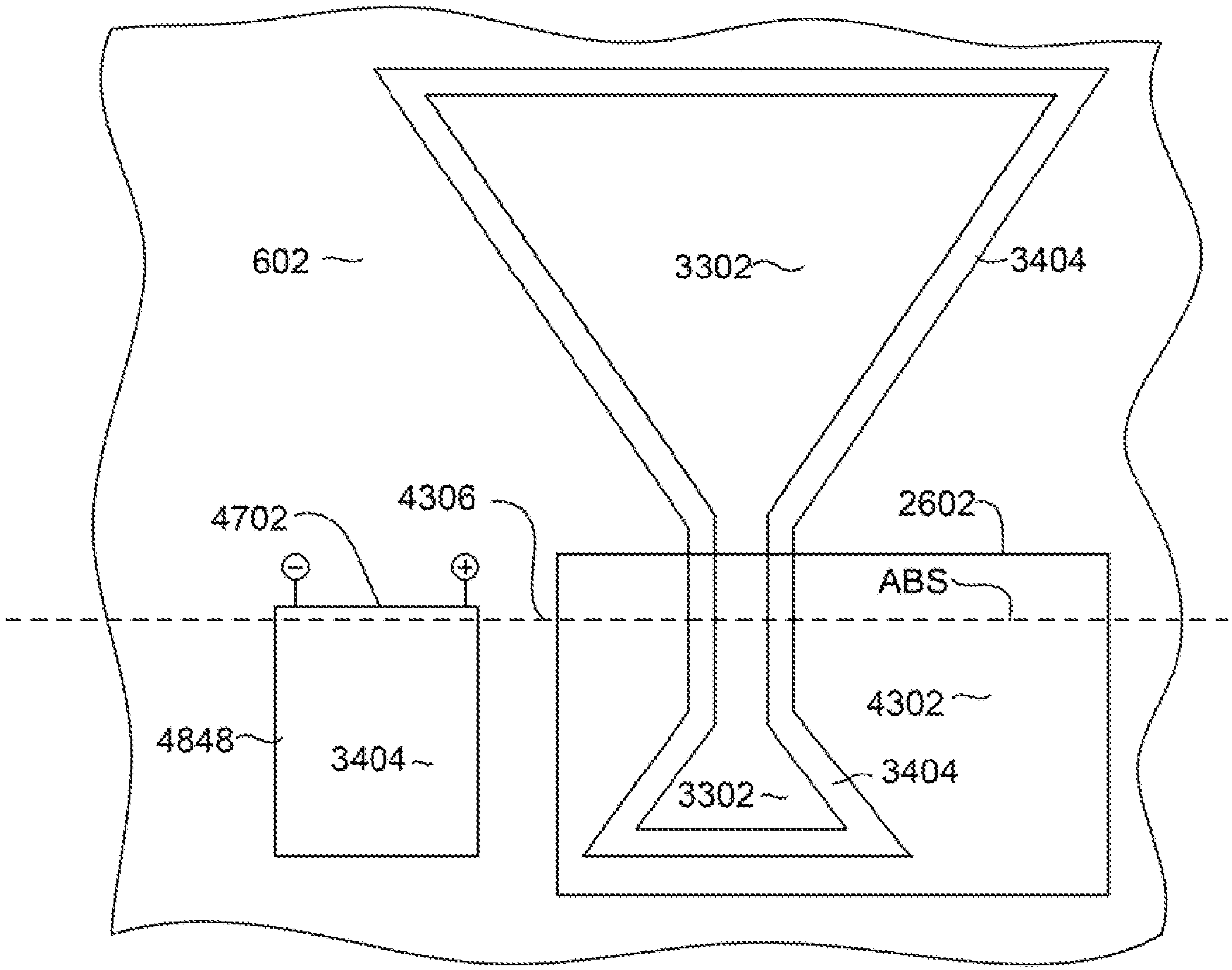

FIG. 48

METHOD FOR MANUFACTURING A MAGNETIC WRITE HEAD

RELATED APPLICATIONS

The present invention is a divisional application of commonly assigned U.S. patent application Ser. No. 11/683,972, entitled PERPENDICULAR WRITE HEAD HAVING A STEPPED FLARE STRUCTURE AND NON-MAGNETIC SPACER LAYER AND METHOD OF MANUFACTURE THEREOF, which was filed on Mar. 8, 2007.

FIELD OF THE INVENTION

The present invention relates to the construction of perpendicular magnetic write heads and more particularly to the use of an optical lapping guide for accurately defining the write pole flare point of a perpendicular magnetic write head.

BACKGROUND OF THE INVENTION

The heart of a computer's long term memory is an assembly that is referred to as a magnetic disk drive. The magnetic disk drive includes a rotating magnetic disk, write and read heads that are suspended by a suspension arm adjacent to a surface of the rotating magnetic disk and an actuator that swings the suspension arm to place the read and write heads over selected circular tracks on the rotating disk. The read and write heads are directly located on a slider that has an air bearing surface (ABS). The suspension arm biases the slider toward the surface of the disk, and when the disk rotates, air adjacent to the disk moves along with the surface of the disk. The slider flies over the surface of the disk on a cushion of this moving air. When the slider rides on the air bearing, the write and read heads are employed for writing magnetic transitions to and reading magnetic transitions from the rotating disk. The read and write heads are connected to processing circuitry that operates according to a computer program to implement the writing and reading functions.

The write head traditionally has included a coil layer embedded in one or more insulation layers (insulation stack), the insulation stack being sandwiched between first and second pole piece layers. A gap is formed between the first and second pole piece layers by a gap layer at an air bearing surface (ABS) of the write head and the pole piece layers are connected at a back gap. Current conducted to the coil layer induces a magnetic flux in the pole pieces which causes a magnetic field to fringe out at a write gap at the ABS for the purpose of writing the aforementioned magnetic transitions in tracks on the moving media, such as in circular tracks on the aforementioned rotating disk.

In current read head designs a spin valve sensor, also referred to as a giant magnetoresistive (GMR) sensor, is employed for sensing magnetic fields from the rotating magnetic disk. The sensor includes a nonmagnetic conductive layer, hereinafter referred to as a spacer layer, sandwiched between first and second ferromagnetic layers, referred to as a pinned layer and a free layer. First and second leads are connected to the spin valve sensor for conducting a sense current therethrough. The magnetization of the pinned layer is pinned perpendicular to the air bearing surface (ABS) and the magnetic moment of the free layer is located parallel to the ABS, but free to rotate in response to external magnetic fields. The magnetization of the pinned layer is typically pinned by exchange coupling with an antiferromagnetic layer. The thickness of the spacer layer is chosen to be less than the mean free path of conduction electrons through the sensor. With this arrangement, a portion of the conduction electrons is scattered by the interfaces of the spacer layer with each of the pinned and free layers.

When the magnetizations of the pinned and free layers are parallel with respect to one another, scattering is minimal and when the magnetizations of the pinned and free layer are antiparallel, scattering is maximized. Changes in scattering alter the resistance of the spin valve sensor in proportion to cos θ, where θ is the angle between the magnetizations of the pinned and free layers. In a read mode the resistance of the spin valve sensor changes proportionally to the magnitudes of the magnetic fields from the rotating disk. When a sense current is conducted through the spin valve sensor, resistance changes cause potential changes that are detected and processed as playback signals.

Recently, researchers have focused on the development of perpendicular magnetic recording systems in order to increase the data density of a recording system. Such perpendicular recording systems record magnetic bits of data in a direction that is generally perpendicular to the surface of the magnetic medium. A write head used in such a system generally includes a write pole having a relatively small cross section at the air bearing surface (ABS) and a return pole having a larger cross section at the ABS. A magnetic write coil induces a magnetic flux to be emitted from the write pole in a direction generally perpendicular to the plane of the magnetic medium. This flux returns to the write head at the return pole where it is sufficiently spread out and weak that it does not erase the signal written by the write pole.

The write pole typically has a flare point that is recessed a desired distance from the ABS. This flare point distance is a critical dimension that must be carefully controlled. The write head may also include a trailing magnetic shield that can be used to increase the field gradient and increase the write speed. The trailing shield has a thickness as measured from the ABS that defines a throat height of the trailing shield. The throat height of the trailing shield is another critical dimension that also must be carefully controlled.

However, as the size of magnetic heads decreases, variations in currently available tooling and photolithography processes make it impossible to control the flare point and trailing shield throat height with sufficient accuracy. Therefore, the inability to accurately control the flare point and trailing shield throat height is limiting the ability to further shrink write head sizes, and is therefore limiting any increase in data capacity.

Therefore, there is a strong felt need for a structure or process that can very accurately define and control the flare point of a write head and the throat height of a magnetic shield in a magnetic write head. Such a structure or process must also be manufacturable using currently available tooling and processes.

SUMMARY OF THE INVENTION

The present invention provides a method for aligning a structure with a lapping guide. The method includes first providing a substrate, and then depositing an electrically conductive material over a first portion of the substrate. A mask structure is formed, having an edge located in the first portion of the substrate and over the electrically conductive material and an edge located in a second portion of the substrate where a structure is to be formed. A material removal process is performed to remove portions of the electrically conductive material not covered by the mask, and electroplating a material over the second portion of the substrate.

This process allows an edge of the electrically conductive material (which can form the lapping guide) to be self aligned with the electroplated material, both the electrically conductive lapping guide material and the electroplated material having an edge that is defined by the same masking step. This, therefore, allows both of these features to be defined in a single photolithographic masking step, eliminating the need to align multiple masks.

These and other features and advantages of the invention will be apparent upon reading of the following detailed description of preferred embodiments taken in conjunction with the Figures in which like reference numerals indicate like elements throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of this invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings which are not to scale.

FIG. **1** is a schematic illustration of a disk drive system in which the invention might be embodied;

FIG. **2**; is an ABS view of a slider, taken from line **2-2** of FIG. **3**, illustrating the location of a magnetic head thereon;

FIG. **3** is a cross sectional view of a magnetic head taken from line **3-3** of FIG. **2**, enlarged, and rotated 90 degrees counterclockwise illustrating an embodiment of the invention incorporated into a perpendicular magnetic write head;

FIG. **4** is an ABS view taken from line **4-4** of FIG. **3** of a write head;

FIG. **5** is a top down view taken from line **5-5** of FIG. **4**;

FIGS. **6-14** show a write head in various intermediate stages of manufacture illustrating a method of manufacturing a write head;

FIG. **15** is a side cross sectional view of a magnetic head according to an alternate embodiment of the invention;

FIG. **16**A is an ABS view taken from line **16**A-**16**A of FIG. **15**;

FIG. **16**B is a cross sectional view taken from line **16**B-**16**B of FIG. **15**;

FIGS. **17-30** are views of a write head in various intermediate stages of manufacture illustrating a method of manufacturing a magnetic write head according to an alternate embodiment of the invention;

FIG. **31** is a side, cross-sectional view of a magnetic head according to yet another embodiment of the invention;

FIG. **32** is a cross-sectional view taken from line **32-32** of FIG. **31**;

FIGS. **33-37** are views of a magnetic head in various intermediate stages of manufacture illustrating a method of manufacturing a magnetic head;

FIG. **38-42** are views of a magnetic head in various intermediate stages of manufacture illustrating a method of manufacturing a magnetic head according to an alternate embodiment of the invention; and

FIGS. **43-48** are top down views illustrating a method of forming a self aligned electrical lapping guide for accurately defining an air bearing surface (ABS) of magnetic write head.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following description is of the best embodiments presently contemplated for carrying out this invention. This description is made for the purpose of illustrating the general principles of this invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **1**, there is shown a disk drive **100** embodying this invention. As shown in FIG. **1**, at least one rotatable magnetic disk **112** is supported on a spindle **114** and rotated by a disk drive motor **118**. The magnetic recording on each disk is in the form of annular patterns of concentric data tracks (not shown) on the magnetic disk **112**.

At least one slider **113** is positioned near the magnetic disk **112**, each slider **113** supporting one or more magnetic head assemblies **121**. As the magnetic disk rotates, slider **113** moves radially in and out over the disk surface **122** so that the magnetic head assembly **121** may access different tracks of the magnetic disk where desired data are written. Each slider **113** is attached to an actuator arm **119** by way of a suspension **115**. The suspension **115** provides a slight spring force which biases slider **113** against the disk surface **122**. Each actuator arm **119** is attached to an actuator means **127**. The actuator means **127** as shown in FIG. **1** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **129**.

During operation of the disk storage system, the rotation of the magnetic disk **112** generates an air bearing between the slider **113** and the disk surface **122** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **115** and supports the slider **113** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **129**, such as access control signals and internal clock signals. Typically, the control unit **129** comprises logic control circuits, storage means and a microprocessor. The control unit **129** generates control signals to control various system operations such as drive motor control signals on line **123** and head position and seek control signals on line **128**. The control signals on line **128** provide the desired current profiles to optimally move and position slider **113** to the desired data track on disk **112**. Write and read signals are communicated to and from write and read heads **121** by way of recording channel **125**.

With reference to FIG. **2**, the orientation of the magnetic head **121** in a slider **113** can be seen in more detail. FIG. **2** is an ABS view of the slider **113**, and as can be seen the magnetic head including an inductive write head and a read sensor, is located at a trailing edge of the slider **209**. The ABS plane of the slider may include pads or recessions **202** relative to the ABS plane of the slider. The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. **1** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

With reference now to FIG. **3**, the magnetic head **121** for use in a perpendicular magnetic recording system is described. The head **121** includes a write element **302** and a read element **304**. The read element **304** includes a magnetoresistive read sensor **305**. The sensor **305**, could be, for example, a current in plane giant magnetoresistive sensor (CIP GMR), a current perpendicular to plane giant magnetoresistive sensor (CPP GMR) or a tunnel junction sensor (TMR). The sensor **305** is located between first and second magnetic shields **306**, **308** and embedded in a dielectric material **307**. The magnetic shields **306**, **308**, which can be constructed of for example CoFe, NiFe or sendust, absorb magnetic fields, such as those from up-track or down-track data signals, ensuring that the read sensor **305** only detects the desired data track located between the shields **306**, **308**. A non-magnetic, gap layer **309** may be provided between the shield **308** and the write head **302**. If the sensor **305** is a CIP GMR sensor, then the sensor will be insulated from the shields **306**, **308** as shown in FIG. **3**. However, if the sensor **305** is a CPP GMR sensor or TMR sensor, then, the top and bottom of the sensor **305** can contact the shields **306**, **308** so that the shields can act as electrically conductive leads for supplying a sense current to the sensor **305**.

With continued reference to FIG. **3**, the write element **302** includes a write pole **310** that is magnetically connected with a magnetic shaping layer **312**, and is embedded within a non-magnetic material **311**. The write pole **310** has a small cross section at the air bearing surface and is constructed of a magnetic material. The write head **302** also includes a return pole **314** that is constructed of a magnetic material such as CoFe, NiFe, or their alloys and has a cross section parallel to the ABS surface that is significantly larger than that of write pole **310**. The return pole **314** can be magnetically connected with the shaping layer **312** and write pole **310** by a back gap portion **316** as shown in FIG. **3**. The return pole **314** and back gap **316** can be constructed of, for example, NiFe, CoFe, or their alloys or some other magnetic material.

An electrically conductive write coil **317**, shown in cross section in FIG. **3**, passes through the write element **302** between the pole layer **402**, and the return pole **314**. The coil **317** is embedded in an insulation layer **330** that can be, for example, alumina and can include one or more layers of one or more materials.

When a current passes through the coil **317**, the resulting magnetic field causes a magnetic flux to flow through the pole layer **402**, return pole **314**, back gap **316**, shaping layer **312** and write pole **310** and possibly some magnetic material in the adjacent media **333**. This magnetic flux causes a write field to be emitted toward an adjacent magnetic medium **333**. This magnetic field emitted from the write pole **310** magnetizes a relatively higher coercivity, thin top magnetic layer on the magnetic medium **333**. This magnetic field travels through a magnetically soft underlayer of the magnetic medium to the return pole **314**, where it is sufficiently spread out that it does not erase data elsewhere on the media **333** that is not located directly under the write pole **310**.

With reference to FIG. **4**, which shows an ABS view of the write element **302**, it can be seen that the write pole **310** preferably has a trapezoidal shape. This shape helps to reduce skew related adjacent track interference. Although not shown, the trailing shield could be constructed to wrap around the sides of the write pole **310**, in which case the side portions of the trailing shield would be separated from the sides of the write pole **310** by a non-magnetic side gap material.

With reference to FIGS. **3**, **4** and **5**, it can be seen that the write pole **310** has a stepped flare structure. More particularly, the write pole **310** includes a magnetic core **402** that is preferably constructed of a lamination of magnetic layers such as NiFe or CoFe separated by thin non-magnetic layers such as alumina. Other materials that can be used in such a laminated write pole include silica, Ta, Ti, NiP, Pd, si, Cr, Mo, Rh, Ru and Al. The write pole **310** also includes a magnetic shell portion **404**, constructed of an electroplated magnetic material such as NiFe, CoFe, or their alloys that wraps around the magnetic core **402**. With reference to FIG. **4**, it can be seen that the magnetic shell **404** is laterally symmetrical about the core **402**. By laterally symmetrical, it is meant that the shell **404** is symmetrical in the track width direction, to the left and right as shown in FIG. **4**.

With reference to FIG. **5**, which shows a view of the deposited end of the slider, it can be seen that the shell **404** forms a stepped structure **406** that is recessed from the ABS. In FIG. **5**, the portions of the core **402** that are hidden within the shell **404** are shown in dashed line, and as can be seen, the core **402** has a flare point **408** that is recessed from the ABS by a first distance FP**1**. However, the stepped structure **406** formed by the front most edge (ABS facing edge **410**) of the shell, defines a secondary flare point that is recessed by a distance FP**2** from the ABS, FP**2** being smaller than FP**1**.

As write heads become ever smaller, the flare point distance from the ABS must become smaller as well. However, available manufacturing processes such as photolithography have resolution and variation limitations that limit the size and placement to which the flare point distance can be defined. For example, currently available photolithographic processes have variations that are sufficiently great that for very small write pole sizes, the location of the flare point in a standard write pole would vary between a write pole having a flare point that is too large to a write pole having no flare point at all. A flare point that is too large would choke off the flux, significantly reducing the write field. A flare point that is too small (or even non-existent) results in an extremely wide write signal that writes to several adjacent tracks. Both of these situations are of course unacceptable. The secondary flare point **406** provided by the magnetic shell **404** allows the location of the flare point FP**2** to be carefully controlled using currently available photolithographic tools and techniques, as will be described below.

The details of the electroplating bath and process are also relevant. The material that is electroplated should preferably be ferromagnetic, but could consist of more than one layer where one layer is ferromagnetic and another is non-ferromagnetic. An example of a non-magnetic layer could be NiP alloy or Pd alloy. Plating such an alloy is a balance between bath composition, plating area, current density and other factors. Other factors include anode and cathode material, voltage or current variations, bath composition including additives, surfactants, buffering, and complexing agents, plating cell design, bath temperature, plating flow rate, wafer mask design, and magnetic field.

In order to electroplate a thin magnetic layer, it is important to control the plating process. Therefore, the plating rate should preferably be less than 100 nm/min. The thin plated layer should be conformal and not introduce increased roughness or morphology to the surface. Preparation of the surface to plate a thin layer could include pre-wetting the surface or using surfactants in the bath. Additives can also be added that will slow the plating process in order to achieve improved thickness control. Another important factor in thin plating is the dwell time which is the amount of time that the wafer sits in the bath prior to applying a potential to the wafer. This dwell time should be minimized because the bath can actually etch or corrode the very material one would want to plate upon (ie. the anode).

A method for minimizing the dwell time in the plating bath is to have a voltage applied to the cathode or anode prior to placement in the plating bath. Therefore, once a wafer enters the plating bath, the circuit is complete and electroplating begins instantaneously. This is referred to hereinafter as a "hot start" process because the wafer can be "hot" by having a voltage on it outside the plating bath which is similar to a live, ungrounded wire.

Plating methods can also affect the material properties and its final thickness. One pulse plating method includes applying a series of voltage or current pulses that plate material in a non-continuous method. This will have the end result of having a slower average overall plating rate compared to the plating rate during a pulse. Reducing the pulse frequency or voltage can slow the plating process. One can even briefly reverse the potential on the wafer and etch (or de-plate) briefly to slow or alter the final plated film.

With reference now to FIGS. **6**-**14**, a method for manufacturing a magnetic write head **302** such as that described above will be described. With particular reference to FIG. **6**, a substrate or under-layer **602** is provided. The substrate **602** can be, for example, the fill layer **330** and shaping layer **312** described with reference to FIG. **3**. Other structures or devices in a head may also be in or below the under-layer **602**. The fill layer **330** can be constructed of alumina. A layer of magnetic pole material **604** is deposited over the substrate **602**. The magnetic pole material **604** can be constructed of several materials, and is preferably a lamination of magnetic layers such as CoFe, NiFe, or their alloys separated by thin non-magnetic layers such as alumina, silicon dioxide or some other material. A mask structure **606** is formed over the magnetic layer **604**. The mask structure can include various layers such as one or more hard mask layers, one or more image transfer layer, and a mask material such as photoresist or thermal image resist. With reference to FIG. **7** it can be seen that the mask structure **606** is configured to define a write pole structure that extends beyond the plane of the Air Bearing Surface (ABS).

With reference now to FIG. **8**, a material removal process such as ion milling, or some other process is performed to remove portions of the magnetic material **604** that are not protected by the mask structure **606** to form a write pole structure **604**. The material removal process, represented by slanted arrows **802** can be performed, for example, by directing an ion beam at an angle or combination of angles relative to normal to form the write pole with a trapezoidal shape as shown in FIG. **8**. With reference to FIG. **9**, the remaining mask material **606** can be removed by one or more of various material removal processes, which may include reactive ion milling, reactive ion etching, etc. This results in a structure as shown in FIGS. **9** and **10** with a write pole structure **604** formed over the substrate **602**. One should also note that the particular method of making the initial pole is not central to the structure or methods described herein. Alternatively, the pole **604** could be formed by electroplating and may be formed without non-magnetic lamination layers.

With reference now to FIG. **11**, a liftoff process can be used to create a plating seed on a portion of the write pole. For example, a bi-layer photoresist mask **1102** can be formed to cover a majority of the write pole structure **604**, leaving a portion of the write pole uncovered. Then, an electrically conductive, magnetic seed layer **1104** such as NiFe or Ta and/or Ir, Rh, etc. can be deposited such as by sputter deposition. The mask **604**, can then be lifted off by a chemical liftoff process. The overhanging structure of the bi-layer mask facilitates the mask liftoff by allowing a liftoff chemical solution to reach under the edges of the mask **1102**. The resulting seed layer **1104** covering a portion of the write pole **604** (preferably near the back edge of the write pole **604**) can be seen with reference to FIG. **12**. The portions of the write pole **604** that are hidden under the seed layer **1104** are shown in dashed line in the cross-hatched portion of FIG. **12**. There would also, preferably, be seed **1104** deposited between devices as well.

With reference now to FIG. **13**, a mask structure, such as a photoresist mask **1302** is formed over a front portion of the write pole **604**. As can be seen, the mask **1302** has a back edge **1304** that is located a desired distance behind the ABS plane designated (ABS). As will be seen, the location of this back edge **1304** determines the amount by which the secondary flare structure **406** (described with reference to FIG. **5**) is recessed from the ABS. In other words, the location of the back edge **1304** determines the flare point (FP**2**) of the finished write head.

After, the mask **1302** has been formed, an electroplating process can be used to deposit an electrically conductive magnetic material such as NiFe, CoFe, or their alloys. This results in magnetic material being plated onto portions of the pole that are not covered by the mask **1302**. With reference to FIG. **14**, a cross section of a portion of the write pole **604** shows that the magnetic material **1402** is plated evenly over the write pole **604**. Therefore, the electroplating results in a laterally symmetrical deposition of magnetic material **1402** onto the portions of the write pole **604** that are not covered by the mask **1302** (FIG. **13**). By laterally symmetrical, it is meant that the deposition of magnetic material **1402** is symmetrical in a track width direction (ie. to the right and left and above as shown in FIG. **14**).

The above described process results in a write pole structure such as the write pole **310** described with reference to FIGS. **3**-**5** above. As will be appreciated by those skilled in the art, inherent process limitations such as photolithographic variation, limit the amount by which the flare point distance can be reduced in a very small write head using a standard write pole structure and standard processes. The above described process makes it possible to construct a write pole having very reduced effective flare point (ie. flare point **406** in FIG. **5**) using currently available manufacturing processes, and currently available photolithographic tools. The present invention, therefore, allows the reduction of write head sizes for current and future write head fabrication.

Sacrificial Fill Layer:

The above described method for manufacturing a write head included a method of forming a write pole having a secondary flare point (FP**2**) formed by electroplating a stepped structure over a write pole. With reference now to FIGS. **15** and **16** a write head is described that has a stepped secondary notch structure similar to that described above, but which also has a wrap around trailing shield. With particular reference to FIG. **1**S a magnetic read/write head **1502** according to an embodiment of the invention has a write head **1504** that has a trailing shield **1506** constructed to wrap around the sides of the write pole **310** and constructed of a magnetic material such as CoFe, NiFe, or their alloys. The trailing shield **1506** is separated from the write pole **310** by a non-magnetic gap material **1508** such as alumina (Al_2O_3) and/or Ta/Rh, Ta/Ir, or Au. The trailing shield has a throat height (TH) that is measured from the ABS to its back edge adjacent to the end of the magnetic shell portion **1510**.

The write head **1504** includes a write pole **310** similar to that described above, which includes a magnetic shell stepped structure **404** that wraps around the top and sides of the main pole portion **402** as seen in FIG. **6**B at a location recessed from the ABS. A non-magnetic spacer layer **1510** wraps around the top and sides of the stepped magnetic structure **404** as can also be seen in FIG. **16**B. The non-magnetic spacer can be constructed of an electroplatable, non-magnetic material, such as NiP, and as can be seen in FIG. **16**B, both the magnetic step structure **404** and the non-magnetic spacer **1510** are laterally symmetrical at either side of the main write pole portion **402**.

With reference now to FIG. **16**A, it can be seen that the trailing shield wraps around the sides of the write pole **310**, the sides of the write pole **310** being separated from the trailing shield **1506** by non-magnetic side gap layers **1512**, which may be the same material as the trailing gap **1508** (such as alumina and/or Ta/Rh, Ta/Ir, or Au.) or could be some other material. The trailing edge **1514** of the write pole **310** is separated from the trailing shield **1506** by a trailing gap distance (TG), and the sides of the write pole **310** are separated from the wrap around portions of the trailing shield by a side gap (SG). SG and TG can be different from one another, with the side gap SG being preferably (but not necessarily) larger than the trailing gap TG.

With reference again to FIG. **15**, it can be seen, that the trailing shield **1506** can be magnetically connected to the return pole **314** or an additional pole that has the same magnetic state as the return pole **314**. Alternatively, the trailing shield **1506** can be a floating shield that is not magnetically connected to the other magnetic structures of the write head **1504**.

With reference now to FIGS. **17**-**30** a possible method is described for constructing a write head such as the write head **1504** described above. With particular reference to FIG. **17**, a substrate **1702** is provided. The substrate **1702** can include an underlying non-magnetic, electrically insulating material such as **330** such as alumina and may include all or a portion of the shaping layer **312**, both of which are described above with reference to FIG. **15**. Optionally a non-magnetic under-layer material **1703** such as TaOx can be deposited over the substrate **1702**. The under-layer **1703** can be helpful in reducing undercut of the write pole during fabrication as will be described in greater detail herein below. A magnetic write pole material **1704** is deposited over the substrate **1702**, and over the under-layer **1703** if present. The write pole layer **1704** can be constructed of several magnetic materials, such as NiFe, CoFe, or their alloys but is preferably a laminated structure that includes layers of a magnetic material such as CoFe separated by thin non-magnetic layers such as alumina.

One or more masking layers **1706** are deposited over the write pole material layer **1704**. Although the mask **1706** can include various configurations and material combinations, the mask **1706** preferably includes a hard mask structure **1707** formed over the write pole material **1704** and resist such as photoresist or thermal image resist **1714**. The hard mask structure **1707** can be a tri-layer first hard mask structure, having a first layer **1705** a second layer **1708** and a third layer **1709**. The first layer is preferably a material that is resistant to removal by chemical mechanical polishing (CMP) such as DLC (diamond-like carbon), Ta Rh, Ir, Ru, Cr or their combination. The second layer **1708** is preferably a material that is resistant to ion milling, such as alumina (Al_2O_3) and can have a thickness of about 20 nm. The third layer **1709** of the first hard mask structure **1707** is also preferably resistant to ion milling and is preferably constructed of AlTio or Al containing alloy, and can have a thickness of about 50 nm.

A method used to create the pole can be one in which the mask **1707** becomes part of the non-magnetic trailing gap (TG) **1709** and is used as an endpoint detection layer during ion milling to define, in part, the non-magnetic side gap (SG) and removes the transfer mask **1710**. In this case, the mill resistant material chosen for **1708** should have a bulk material of **1709** with a small percentage of doped material for endpoint detection. For example, a layer **1708** would be comprised of Al_2O_3 and the gap **1709** preferably has Al_2O_3 doped with Ti where the material to detect for end point would be Ti. However, the layer **1709** could be doped (less than 10% by weight) with another material that can be clearly detected using an end point detection signal.

The mask structure **1709** can also include an image transfer layer **1710** formed over the first hard mask structure **1707**. The image transfer layer can be a soluble polyimide material such as DURAMIDE®. A second hard mask **1712** can be provided over the image transfer layer **1710** and can be constructed of SiO_2 having a thickness of about 125 nm. An antireflective coating layer **1713** can be provided over the second hard mask **1712**. The antireflective coating layer **1713** can be constructed of the same material as the image transfer layer **1710** (eg. a soluble polyimide solution such as DURAMIDE®), and can have a thickness about 120 nm. The resist mask layer **1714** can have a thickness of about 250 nm and can be deposited over the antireflective coating layer **1713**.

With reference now to FIG. **18**, the resist layer **1714** is photolithographically patterned and developed to have a shape that is configured to define a write pole. Then, with reference to FIG. **19**, one or more material removal processes **1902** are performed to transfer the image of the photoresist layer onto the underlying mask layers. The material removal processes preferably include a combination of reactive ion etching (RIE) and reactive ion milling (RIM), which remove the remove portions of the mask layers **1708**, **1709**, **1710**, **1712** and **1713**, while leaving the first sub-layer **1705** of the first hard mask **1707** substantially intact to protect the magnetic write pole layer **1704** from being damaged by the material removal processes **1902**.

Then, with reference to FIG. **20**, an ion milling process **2002** is performed by directing an ion beam at an angle relative to normal to remove portions of the magnetic write pole material **1704** that are not protected by the mask structure **1706**. It can be seen that while some of the mask structure **1706** is consumed by the ion milling **1706**, a considerable portion remains. The angled ion milling **2002** results in the write pole **1704** having a desired trapezoidal shape, such as is shown in FIG. **20** and which has been previously discussed above.

With reference now to FIG. **21**, a non-magnetic side gap material **2202** is deposited. The side gap material can be alumina (Al_2O_3) and is preferably deposited by a conformal process such as atomic layer deposition (ALD) or some other conformal process.

The side gap material **2202** could also be a non-magnetic metal. If a metal is used as the side gap material **2202**, then it must be a material that can remain in the ABS without presenting corrosion problems. Then, with reference to FIG. **22**, a fill material **2204** is deposited. This fill material **2204** is preferably a material that can be readily removed without damaging the write pole material. For example, in one preferred embodiment, the fill material **2204** can be a material such as SiO_2, which can later be removed by a process that will be described below. In another preferred embodiment, the fill material **2204** can be a material such as Cu or some other non-magnetic material.

With reference now to FIG. **23** a chemical mechanical polishing process (CMP) is performed to planarize the structure and remove most of mask layer **1706** from over the pole **1704**. The bottom layer **1705** can be used as a CMP stop layer so that CMP can be stopped when the layer **1705** is reached. The remaining mask material (CMP stop layer) **1705** (FIG. **22**) can be left intact and becomes part of TG or can be removed by a material removal process suited to the material making up the layer **1705**. For example, if the layer **1705** is diamond like carbon (DLC) it can be removed by using an oxygen containing reactive ion etch (RIE) plasma. Then, with reference to FIG. **24**, the fill material **2204** can be removed. If the fill layer **2204** is a material such as silicon dioxide (SiO_2), then the fill layer **2204** can be removed by a fluorine containing reactive ion etching (RIE) plasma or reactive ion milling (RIM) beam. Alternatively, the fill and CMP process can be omitted and a reactive ion milling process (RIM) can be used to remove the mask structure **1710**. In that case, the bottom mask layer **1705** (such as Ti or Rh) or **1709** can be used as an etch stop indicator using secondary ion mass spectroscopy (SIMS) to detect when the layer **1705** has been reached. The selection of a layer **1705** or layer **1709** which comprises an end point material enables the ability to control TG thickness. One can also insert more than one end point layer, such as one in layer **1705** and layer **1709**. This gives the manufacturing of heads the flexibility of altering the trailing gap (TG) for different products having different gap targets. This can also affect the associated side gap (SG). Furthermore, the end point materials in the two layers could be comprised of different materials (eg. Ti for one layer and Ta for another end point layer).

The above described processes result in a write pole having non-magnetic side walls **2204** and a non-magnetic trailing gap layer **1705** formed over the write pole **1704**.

If the fill material **2204** is Cu, then a different process can be performed to remove it after the CMP. One method that can be employed to remove the Cu fill layer **2204** is emersion in a basic complexing etch bath that will not readily etch the CoFe pole material **1704**. The Cu fill layer **2204** could also be removed by electroetching.

With reference now to FIGS. **5**, **25** and **26**, a photoresist mask **2502** is formed. As can be seen in FIG. **26**, the mask **2502** has a back edge **2602** that is located behind the ABS plane between the ABS plane and the flare point **408** of the write head **1704**. As shown in FIG. **26**, the portions of the pole **1704** and side walls **2202** that are hidden beneath the photoresist mask **2602** are shown in dotted line.

Then, with reference to FIG. **27**, a material removal process is performed to remove portions of the sidewall material **2202**. If the side wall material **2202** is alumina, it can be removed by an etching process that is designed to remove the alumina side wall material **2202** without damaging or removing the pole material (eg. CoFe). Possible etching solutions include a metal ion free developer solution such as tetramethylammonium hydroxide (TMAH), KOH, or a chrome etch such as CR-7® produced by Cyantek® of Fremont, Calif. The choice of what etchant to use will depend upon the side-gap material **2202**. Whatever method of etching is used, it must cleanly remove all of the side wall material, to insure effective plating of a magnetic material onto the pole **1704** as will be described in greater detail herein below. If the side gap **2202** material is a Zn alloy, it can be removed from the area behind the mask **2502** by electroetching. If the side gap **2202** is constructed of silicon oxide (SiOx) it can be removed etching with an HF acid that is buffered (BOE). This results in a structure as shown in FIG. **27**.

With reference now to FIG. **28**, which shows a cross section of the write pole in a region beyond the back edge **2602** of the mask **2502** (shown in FIG. **27**), a magnetic material **2802** can be electroplated onto the portion of the pole **1704**. This magnetic material **2802** can be, for example CoFe, NiFe, or their alloys and is preferably CoFe. This magnetic material forms a stepped structure on the write pole similar to the step **406** described in FIG. **4**, and is similar to FIG. **16**B where the plated materials **2802** and **2804** may be the same as **404** and **1510** as seen in FIG. **16**B. In order for this stepped pole structure to function optimally, there must be no non-magnetic remnant material left between the pole **1704** and the magnetic material **2802**. This is one reason that the above described process used to remove the side wall material **2202** must very effectively remove all of this material. optionally, a non-magnetic gap layer **2804** can then be deposited over the plated magnetic layer **2802**. This non-magnetic layer can be a non-magnetic metal, such as Cu or NiP and can be electroplated directly onto the magnetic layer **2804**.

The resist mask **2502** can then be lifted off, leaving the structure as shown in a side cross sectional view in FIG. **29**. Then, with reference to FIG. **30**, a non-magnetic trailing gap layer **3002** can be deposited. This layer **3002** can be a non-magnetic material such as Ta and/or Rh, Au, and Ir, which can be deposited by a conformal deposition method such as ion beam deposition (IBD). The non-magnetic trailing gap layer **3002** is deposited to such a thickness to provide a desired trailing gap thickness TG and side gap **15**, thickness SG as described in FIG. **16**A. Then a magnetic material **3004** can be deposited by electroplating to provide a magnetic trailing shield, such as the trailing shield **1506** described above with reference to FIG. **15**. A lapping process (not shown) can be used to remove material (from the left side as shown in FIG. **30**) until the ABS plane has been reached, thereby forming a write head with an air bearing surface (ABS) and having a trailing shield **1506** with a desired throat height as measured as measured from the ABS. The above described processes can produce a magnetic write head **1504** such as that described with reference to FIGS. **15**, **16**A and **16**B, having a desired stepped pole structure **310** with a trailing shield **1506**.

Write Head with Stair Stepped Trailing Shield:

With reference now to FIG. **31** a magnetic write head **3102** having a stair stepped trailing shield **3104** is described. The write head includes a magnetic write pole **3106**, that has a core portion **3108** similar to the core **402** described above with reference to FIGS. **15**, **16**A and **16**B. The pole **3106** also has a magnetic shell portion **3110** that is similar to the magnetic shell **404** described with reference to FIGS. **15** and **16**B. The trailing shield **3104** can also act as a return pole **314** as seen in FIG. **31**A.

In addition, the write head **3102** includes a non-magnetic spacer layer **3112**. The non-magnetic spacer layer **3112** is similar to the spacer **1510** described with reference to FIGS. **15** and **16**B in that it wraps around the top and sides of the stepped magnetic shell structure **3110** as shown in FIG. **32**. However, as can be seen in FIG. **31**, the non-magnetic spacer structure is stepped back from the ABS. In other words the magnetic shell has a front edge **3114** that is recessed from the ABS by a first distance, and the non-magnetic spacer **3112** has a front edge that is spaced from the ABS by a second distance that is greater than the first distance. The trailing shield **3104** is separated from the pole **3106** by a spacer **3112** comprising, for example, NiP and a non-magnetic trailing gap material **3120** that could be constructed of, for example, alumina and Ta and/or Rh, Au, and Ir,

This extra recession of the non-magnetic spacer **3112** allows the magnetic shield **3104** to form a stair stepped back edge **3118** that tapers away from the ABS. This results in a magnetic shield **3104** that has a back edge **3122** that is coincident with or recessed beyond the secondary flare point defined by front edge **3114** of the magnetic shell structure **3110**. Although shown as a single stair stepped notch, the number of stair steps could be increased to more closely resemble a smooth taper, if desired.

With reference now to FIGS. **33**-**42** a method is described for constructing a magnetic write head such as the write head **3102** discussed above. With particular reference to FIG. **33**A a magnetic write pole core portion **3302** is formed on a substrate **3101**, with non-magnetic side walls **3304** (preferably alumina) surrounding the magnetic core **3302**. A photoresist mask **3306** is formed over a front portion of the write pole core **3302**, the mask having a back edge **3308** that is between the ABS and the flare point **3310** of the core portion. A material removal process can then be performed to remove the portions of the side wall material **3304** that are not covered by the mask **3306** (ie. beyond the back edge **3308** of the mask **3306**). This can be performed by methods such as those discussed above with reference to FIGS. **17-24**.

Then, with reference to FIG. **34** a magnetic material **3402** such as CoFe is deposited onto the magnetic write pole core **3302**, preferably by electroplating. A non-magnetic metal **3304** such as NiP, ZnNi, Cu, Cr or Au is then deposited onto the magnetic layer **3302**, preferably by electroplating. Then, the resist mask is lifted off, leaving a structure as shown in a side cross sectional view in FIG. **35**A. Similarly, in FIG. **36**, a magnetic and non-magnetic layer containing a stack which is electroplated may have a step between one layer and another where the first edge of one plated layer **3604** is protruding relative to the edge of a second plated layer **3602**.

An example of the process flow is shown in FIG. **33**B, where an existing pole **3315** will have a flare point defined by a masking step **3320**. This is followed an etch of material on the pole **3302** in a step **3602**. However, this is only needed if there is non-magnetic material covering the pole. Then, a magnetic layer is electroplated directly off of the pole **3302** in a step **3340**. Optionally, in a step **3350** one may deform the mask layer after the magnetic layer is plated. In addition step **3360**, an optional non-magnetic portion may be plated on the magnetic plated pole portion. The mask would be removed in a step **3370** and processing would continue **3380**.

Referring to FIGS. **33**A, **33**B, **35**A and **36**, the material removal process **3602** is performed, prior to plating, to remove a portion of the non-magnetic layer **3304**. The material removal process **3602** is a process that is carefully chosen to remove the non-magnetic metal **3304**, without affecting the magnetic layers **3404** or **3302**. This process **3602** can be a wet etch. For example, if the non-magnetic layer **3404** is constructed of ZnNi, it can be removed by electroetching. If the non-magnetic layer **3404** comprises Cu, it can be removed by etching with a basic solution containing ammonium persulfate and ammonium hydroxide. If the non-magnetic layer **3404** is Cr it can be etched with a Cr etchant such as CR-7® produced by Cyantek Corp.®. If the non-magnetic layer **3404** is Au, it can be etched with potassium iodine. As can be seen in FIG. **35**B, the removal of a portion of the non-magnetic layer **3304**, allows for the plating of magnetic layer **3402** and non-magnetic layer **3404**, defining a front edge **3509**. This front edge of **3509** of, at least, the first electroplated layer will define the new flare point **3535**.

Then, with reference to FIG. **37**, a non-magnetic trailing gap layer **3702** such as Ta and/or Rh, Au, and Ir, can be deposited, and a magnetic material **3704** such as NiFe, CoFe, or their alloys can be deposited by electroplating to form a trailing shield having a stair stepped back edge. In this manner, a trailing shield can be constructed that has a back edge **3706** that is either coincident with or behind the flare point defined by the front edge **3604** of the magnetic shell layer **3402**.

With reference now to FIG. **38** a possible method is described for constructing a stair stepped shield structure. After constructing a write pole core portion **3302** over an under-layer **1703** and substrate **3101**, a photoresist mask **3802** is formed. Then, a layer of magnetic material **3804** is deposited to form the magnetic shell over the magnetic core **3302**. Then, with reference to FIG. **39**, a soluble material **3902** such as a SAFIER® coating is deposited (ie. spun on) to the structure. The structure thus far formed can then be heated. This heating causes the soluble coating **3902** to contract, pulling the photoresist mask **3802** with it, resulting in a structure as shown in FIG. **40**, with the mask **3802** overlapping the magnetic shell **3804**. Then, with reference to **41**A, the shrinkable coating **3902** can be removed and a non-magnetic metal **4102** can be plated onto the magnetic shell **3804**. Then, with reference to FIG. **42**, a non magnetic gap layer **4202** such as Ta and/or Rh, Au, and Ir, which can be deposited and a magnetic material such as NiFe, CoFe, or their alloys can be deposited by electroplating over the gap layer **4202**. As can be seen, this results in a magnetic shield **4204** having a stair stepped back edge **4206**. Alternatively, a multi-stair structure can be created as shown in FIG. **41**B, where upon some substrate with seed **4101** a multi-step structure is electroplated that comprises more than one material. Similarly, an electroplated feature can be formed as shown in FIG. **41**C. This may comprise one or more materials with one or more steps where each step recession of less than 50 nm makes the structure progressively narrower, as seen in FIG. **41**D. Depending on the head design, the distance from the flare point to the ABS **3737** may be less than, equal to, or greater than the distance from the back edge of the trailing shield and the ABS **3747**.

Self Aligned Electrical Lapping Guide (ELG):

As seen in FIG. **37**, the formation of a magnetic write head, such as the embodiments disclosed above require careful control of flare point (distance between flare point and ABS **3737**) and trailing shield throat height (thickness of the trailing shield as measured from the ABS **3747**). Both the write pole flare point and the trailing shield throat height are measured from the location of the ABS, which in turn is defined by a lapping operation. This lapping operation occurs after the wafer has been cut into rows of sliders. A side of the row of sliders, or an individual slider, is lapped to remove material until a desired ABS plane location has been reached. At this point the row of sliders can be cut into individual sliders. This lapping operation is, however, difficult to control.

An electrical lapping guide (ELG) can be used to determine at what point lapping should be terminated. A lapping guide is an electrically conductive material, with an edge that is at a predefined from, or exactly at, the intended ABS plane. As lapping progresses, the electrical resistance of the lapping guide is measured by applying a voltage across the lapping guide. When this resistance reaches a predetermined level, the operator can determine that the ABS plane has been reached and lapping should terminate.

As can be appreciated, then, defining the location of the edge of the lapping guide must be carefully controlled relative to the intended ABS and relative to the flare point and shield throat height. However, manufacturing tolerances, such as aligning multiple mask photolithographic steps make this edge location control very difficult. The method described herein below provides an accurate self alignment process for accurately and reliably locating the critical edge of the lapping guide, relative to the ABS, flare point and shield throat height.

With reference now to FIGS. **43** and **35**B, a write pole structure **3302** is shown at a manufacturing stage similar to that described with reference to FIG. **26**. This structure includes a write pole core portion **3302** and a non-magnetic side wall **3404** surrounding the write pole core **3302**. An electrically conductive ELG **4304** is formed in a kerf area beside the write pole **3302**. The ELG material can be formed by a liftoff process such as by forming a bi-layer photoresist mask (not shown), depositing an electrically conductive material, and then lifting off the mask. A substractive method could also be used. A mask structure **4302** is formed similar to the mask **2502** described in FIG. **26**, except that this mask structure **4302** has a back edge **4302** that is aligned relative to the intended ABS plane. In fact, the edge **4306** could be located at the ABS plane as shown, or could be at some other predetermined location relative to the ABS plane. The mask **4302** and edge **4306** extend over, at least a part of, the ELG material **4304** as shown in FIG. **43**

With reference now to FIG. **44**, a material removal process such as that described above with reference to FIG. **27** can be performed to remove portions of the non-magnetic side wall **3404** that are not covered by the mask **4302**. This removes the portions of the side wall **3304** that extend beyond the back edge **2602** of the mask **4302**. The same or a different material removal process (such as reactive ion etch) can be used to remove the portion of the ELG **4304** that extends beyond the back edge **4306** of the mask **4302**. As will be recalled from the discussions above, the location of the edge **2602** of the mask **4302** defines the location of the secondary flare point (for example FP**2** in FIG. **5**) as well as the trailing shield throat height (for example TH in FIGS. **15** and **30**). Therefore, by continuing processing as described above with regard to the previously described methods and embodiments, the back edge **4404** of the ELG lapping guide is self aligned with the write head flare point and shield throat height and ABS. One can also say that the edge **4404** is self aligned so that the photo edge **2602** of the mask layer **4302** is used to define the ELG as well as the flare point (FP**2**) and its associated shield throat height TH, there is no need to align multiple masks in multiple photolithographic steps. During lapping, a voltage can be applied across the ELG **4304** to measure the resistance across the ELG. As lapping progresses in a direction as indicated by arrow **3408**, the ELG will be consumed. As a greater and greater portion of the ELG is consumed, the resistance across the ELG will increase, and when a predetermined resistance is reached, lapping can stop. With the back edge located directly at the ABS as shown in FIG. **44**, the lapping can the resistance across the lapping guide **4304** increases to infinity (ie. when the lapping guide **4304** is completely removed) by lapping material away.

With reference to FIG. **43**A, an alternate device that can be patterned is a sensor **4304**. This may exist in a side-by-side head where a write head is co-planar with a sensor structure. Similar to the patterning of the write head ELG material **4304**, the back edge of a sensor **4343** can be defined with the edge **4306** of the mask **4302**. The sensor **4343** would be deposited and possibly partially patterned prior to deposition of the defining mask **4302**. As symbolized in FIG. **44**A, the sensor **4343** would be electrically connected to outside the device. This would result in a head that has the back edge **4444** of the sensor self-aligned to the flare point FP and its associated throat height (TH).

Collectively, one could also define the flare point FP and its associated throat height TH with the back edge **2602** of the mask **4302** along with a coplanar sensor **4343** and a write head ELG material **4304** using variations in the shape of mask **4302**.

With reference now to FIG. **45**, another method for constructing a lapping includes depositing an electrically conductive lapping guide material **4304** such as Au. Then, a mask structure can be formed that includes a first portion **4404***a* having a back edge **2602** located to define a flare point FP**2** and its associated shield throat height TH as described above. The mask also includes a portion **4404***b* that has a front edge **4406** located to define a back edge of a lapping guide, which may or may not be co-linear with the ABS plane. Then, with reference to FIG. **46**, an etchable material **4602** such as CoFe can be plated onto the lapping guide material **4304** adjacent to the mask **4404***b*. Although the etchable material **4602** is shown only over the lapping guide region in FIG. **46**, this is for purposes of illustration only. The etchable material **4602** could actually be deposited full film, as it will be later removed by etching. Then, the mask portion **4404***b* can be removed leaving a non-plated portion **4510** on the lapping material **4304**. Then, etching the non-plated portion **4510** creates the back edge of the write head ELG. The plated material **3404** that was electroplated on the ELG material **4304**, as well as the ELG material **3404** itself, collectively form an ELG that has a back edge **4702**, as seen in FIG. **47**. Since the mask structures **4404***a* and **4404***b* are defined in the same photolithographic step, the edge **4702** can be accurately aligned with the ABS plane, flare point FP**2** and shield throat height TH, which is defined by the placement of the edge **2602**. Similarly, the ELG **4304** would be electrically connected to enable monitoring the ABS plane by inferring resistance changes in the ELG **4304**. This would create a resistance measurement that would relate the ABS plane to the back edge **4702** of the ELG **4304**.

Furthermore, as seen in FIG. **48**, a similar additive process could have a plated material **3404** on a sensor **4848** where the back edge **4802** of the sensor was created with part of the same mask **4302** that defined the flare point FP and its associated throat height TH.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Other embodiments falling within the scope of the invention may also become apparent to those skilled in the art. Thus, the breadth and scope of the invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A method for manufacturing a magnetic write head, comprising:

providing a substrate;

forming a magnetic write pole over the substrate;

depositing an electrically conductive material;

forming a mask structure having an edge located over the electrically conductive material and also having an edge located over the write pole;

performing a material removal process to remove a portion of the electrically conductive material that is not protected by the mask structure; and

electroplating a magnetic material over a portion of the write pole that is not covered by the mask structure.

2. The method as in claim **1** wherein the mask structure leaves a portion of the electrically conductive material and a portion of the write pole exposed.

3. The method as in claim **1** further comprising, after electroplating the magnetic material, electroplating a non-magnetic material.

4. The method as in claim **3** wherein the electroplated magnetic material and the electroplated non-magnetic material each have an edge that is aligned with the edge of the mask structure.

5. The magnetic method as in claim **3** wherein the electroplated non-magnetic material comprises NiP.

6. The method as in claim **3**, further comprising, before forming the mask structure, forming non-magnetic sidewalls at first and second sides of the write pole, wherein the material removal process removes portions of the non-magnetic side wall that are not protected by the mask structure.

7. The method as in claim **3** wherein the material removal process is a first material removal process, the method further comprising, after forming the mask structure and before electroplating the magnetic material, performing a second material removal process to remove portions of the side walls that are not protected by the mask structure.

8. The method as in claim **1** wherein the material removal process comprises reactive ion etching.

9. The method as in claim **1** wherein the electroplated magnetic material has an edge that is aligned with the edge of the mask structure.

10. The method as in claim **1** wherein the magnetic material comprises NiFe or Co—Fe.

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